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Edited for the Council by J. LAURENCE PRITCHARD, Fellow

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NOTICES

Elections

The following members were elected at a Council Meeting held on April 5th, 1927 :—

Fellow.—Professor W. T. David, M.A. (Cantab.), Sc.D. (Cantab.), D.Sc. (Wales), M.Inst.C.E., M.I.Mech.E.

Associates.—Flying Officer E. C. N. Jeffries, Lord Ossulston, Mr. W. E. Packman, Mr. B. B. Walker, B.Sc. (London), A.M.I.E.E., Mr. L. Hosier-Whatley.

Students.—Mr. L. A. Hodges, Mr. F. Beach.

The Herbert Akroyd Stuart Lectures

The Society has recently been bequeathed the sum of £700 by Mr. Herbert Akroyd Stuart, to be held in trust, in order to provide a Prize once in every two years for the best paper on the subject of "The Origin and Development of Heavy Oil Aero Engines." The lectures or papers which will be delivered under this Trust will be known as "The Herbert Akroyd Stuart Lectures."

Mr. Stuart will be remembered for the Akroyd Cycle Heavy Oil Engines. He was one of the pioneers of the compression ignition engines, and his death will be a great loss to the engineering world.

Halton Aero Club Branch of the Royal Aeronautical Society

A Branch of the Society has recently been formed at the School of Technical Training of the Royal Air Force at Halton. The Chairman of the new Branch is Wing Commander C. D. Breese, A.F.C., A.F.R.Ae.S. The Council wish the new Branch every success.

Donations

The Council desire to acknowledge with thanks the gift of back numbers of the Journal from Mr. F. W. Hills, and of 14/- to the Library Fund from Mr. H. J. Andrews, A.F.R.Ae.S.

Acknowledgment

The five photographs of Major Carter's paper on "Dynamic Forces in Aircraft Engines," reproduced on pages 285-287 of the April Journal, were published by permission of the Air Ministry. The Crown copyright of these photographs is strictly reserved.

Appointment

Mr. Henry Thomas Tizard, C.B., A.F.C., F.R.S., Fellow, has been appointed by His Majesty the King in Council to be Secretary to the Committee of the Privy Council for Scientific and Industrial Research on the retirement of Sir H. Frank Heath, K.C.B., from that office on June 1st next.

Special Lectures

A special lecture has been arranged for Wednesday, May 4th, when Captain Neville Stack, who lately flew to India in a light aeroplane, will read a paper on his flight, illustrated by lantern slides. The lecture will take place at the Royal Society of Arts, 18, John Street, Adelphi, at 6.30 p.m.

Committees and Representatives on Other Bodies

The following Members of Committees and Representatives on other bodies were appointed at a Meeting of Council held on April 5th :—

Candidates' Committee.—Mr. R. A. Bruce, Mr. A. E. L. Chorlton, Mr. R. K. Pierson, Lieut.-Colonel V. C. Richmond, Mr. W. P. Savage and Mr. R. V. Southwell.

Finance Committee.—Mr. J. E. Hodgson, Major D. H. Kennedy, Mr. H. T. Tizard and Mr. F. P. Walsh.

Data Sheets Committee.—Major J. S. Buchanan, Mr. H. B. Irving, Major A. R. Low, Mr. W. O. Manning, Major Mayo, Mr. R. McKinnon Wood, and two representatives from the S.B.A.C.

Informal Discussions Committee.—Mr. M. L. Bramson, Mr. F. A. Foord and Major R. H. Mayo.

Joint Standing Committee with the Society of British Aircraft Constructors and the Royal Aero Club.—Mr. Griffith Brewer, Colonel the Master of Sempill and Sir Vyell Vyvyan.

REPRESENTATIVES ON OTHER BODIES.

British Engineering Standards Association Aircraft Committee.—Major R. H. Mayo and Dr. H. C. Watts.

Central Library for Students.—Mr. J. E. Hodgson (Honorary Librarian).

Students' Section

Mr. S. Scott-Hall, M.Sc., D.I.C., will read a paper on "Polar Exploration and Survey by Air" in the Library at 7, Albemarle Street, W.1, at 7 p.m. on Thursday, May 5th. Mr. Griffith Brewer, F.R.Ae.S., will take the chair.

A visit has been arranged to Vickers, Limited, at Weybridge, for Saturday, May 14th. Members are notified that the party will meet at No. 6 Platform, Waterloo, at 9.5 for the 9.24 train to Weybridge.

An interesting discussion on "Light Planes," opened by Mr. W. E. Gray, was held on Friday, April 8th, the chair being taken by Mr. A. P. Hunt. Twelve out of the thirteen members present took part in the discussion and the view that each town should be encouraged to run its own aerodrome was strongly supported.

Forthcoming Arrangements

Wednesday, May 4th, 6.30 p.m.—At the Royal Society of Arts, 18, John Street, Adelphi, W.C.2. "By Light Aeroplane to India," by Captain T. Neville Stack.

Thursday, May 5th, 7 p.m.—In the Library, 7, Albemarle Street, W.1. "Polar Exploration and Survey by Air," by Mr. S. Scott-Hall, M.Sc., D.I.C.

Tuesday, May 10th, 5.30 p.m.—Council Meeting.

Saturday, May 14th.—Visit to Vickers Limited's Works at Weybridge.

Monday, May 16th, 6.30 p.m.—At the Royal Society of Arts, 18, John Street, Adelphi, W.C.2. Wilbur Wright Memorial Lecture, "Vortices in a Fluid, as Produced by a Small Viscosity," by Professor Prandtl.

J. LAURENCE PRITCHARD, *Secretary.*

PROCEEDINGS

FOURTH MEETING, SECOND HALF, 62ND SESSION

The Fourth Meeting of the Second Half of the 62nd Session of the Royal Aeronautical Society was held in the Theatre of the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on Thursday, February 17th, 1927, when Major R. H. Mayo, O.B.E., Fellow, read a paper on the "Design of Commercial Aircraft from the Operational Point of View." Colonel the Master of Sempill, A.F.C., Associate Fellow, Chairman of the Society, presided.

Colonel the MASTER OF SEMPILL: I am very sorry that the interesting paper you are going to hear to-night could not be circulated before the lecture, but the lecturer, Major Mayo, was away in America, where he was detained for longer than he had anticipated. In consequence he had very little time in which to write this paper which was finished only two days ago.

Major Mayo needs no introduction whatever. He is well-known to all of you, and you will recollect that he joined the staff of the old Royal Aircraft Factory in 1912 where he took part in the work of the late Mr. E. T. Busk. During the War he was engaged in flying and technical work in the Royal Flying Corps and later the R.A.F. Since then he has devoted his attention to commercial aviation; he was a director of Ogilvie and Partners and later of the Aircraft Operating Company. He is consulting engineer to Imperial Airways.

Major Mayo is the representative in this country of the Daniel Guggenheim Fund for the Promotion of Aeronautics, and I should like to take this opportunity of expressing publicly the gratitude of the Society for the donation recently granted by the Trustees of the Fund. The generous cheque which has lately been received from the Fund will enable the work of the Society to be considerably extended.

SOME NOTES ON THE DESIGN OF COMMERCIAL AIRCRAFT FROM THE OPERATIONAL POINT OF VIEW.

BY MAJOR R. H. MAYO.

The original title put down for this paper was "The Design and Operation of Commercial Aircraft." I hope it will be observed that I have actually taken a very much more modest title than that. A paper with so broad a title as the original one might well have been read five or six years ago, but at the present stage of development of commercial aviation, he would be a bold man indeed who would attempt to deal with two such subjects in a single one-hour paper.

It happens that the Society has had two very valuable papers dealing with commercial air transport comparatively recently. I refer in the first place to Sir Sefton Brancker's paper of October, 1925, which gave a very comprehensive review of the progress of civil aviation during its first six years, including a general survey of the development of commercial aircraft design. A little later on we had a most interesting paper by Mr. Cowley dealing with the more theoretical aspects of aircraft transport economy. In view of these two comprehensive papers, there seems little justification for another one on a similar subject at the present time, and I fear I shall be able to add very little of interest to what was contained in those papers. All I can do is to attempt to set out a

few notes based on recent experience in regard to commercial aircraft design as seen from an operating view point, but I intend to take this opportunity of emphasising as strongly as I can the one factor which, to my mind, is of essential importance for the future progress of commercial aviation, namely, the need for attaining the highest possible standard of safety and reliability. I anticipate that some of the opinions which I shall express will meet with the strong disapproval of many aircraft operators. Fortunately commercial aviation is not yet old enough to have reached that dull state of universal agreement which is so paralysing to progress and development. Incidentally I would mention that I recently glanced through a paper I read on a similar subject at the International Air Congress in 1923, and found that I now profoundly disagree with most of the views I then expressed.

Air transport has always been of so much more general interest than other forms of commercial aviation, that the many other important branches of civil aviation which are being developed so rapidly, in other countries if not in England, are apt to be overlooked. In America commercial aviation of other forms than regular transport has been developed so rapidly during the last few years that it is well on the way to becoming an important national industry. There are, I believe, something like 5,000 aircraft operating for private and commercial purposes in the United States at the present time, and in Canada also aircraft have been used for many useful commercial purposes other than transport.

In the present paper it will be convenient to divide the subject into two sections, one dealing with regular air transport and the other with what may be called general air service, a term which is meant to include all the numerous and various applications of aircraft to commercial work, other than transport on regular routes to scheduled services. I shall deal in greater detail with the question of regular air transport, as the technical problems affecting the design of transport aircraft are perhaps of more general interest than in the case of air service aircraft, but I shall attempt to give a summary of the position in regard to the design of aircraft for some of the more important branches of air service. Some of these branches, particularly air survey, involve requirements in the design of the aircraft employed which are of considerable technical interest as they differ so widely from the requirements in the case of regular transport aircraft.

I am afraid it will be necessary to confine the paper mainly to a review of the situation in regard to British design with occasional references to foreign development. I understand that we shall very shortly be hearing a paper from Major Wronsky, who will give us a review of the progress and developments being made from the German point of view, so although one cannot help appreciating the great strides made by German designers during the last few years, I shall not attempt to deal with these developments in my paper.

Air Transport

(i) *Safety the Dominant Factor in Commercial Aircraft Design*

I think that if a general review is made of the development of British design since 1919, it will be seen that nearly all the important progress made has been in the direction of reliability. In saying this I do not mean to imply that there has been no progress in other directions; on the contrary, the present-day commercial aircraft is a more serviceable and a more efficient aircraft than its predecessor of six or seven years ago. I do not think there could be a more striking tribute to the excellence of the general and detail design of modern British aircraft than the flight which has just been successfully completed by the Secretary of State for Air and Lady Maud Hoare, from London to Egypt and Delhi and then back to Cairo. I think it is generally known that the

de Havilland Hercules machine, on which this flight was made, was of an entirely new design, and that this particular machine and the two other machines which flew out to Cairo in December (one of which carried the President of the Society) were only completed and delivered within a few weeks of their departure. They were, of course, thoroughly tested and completely equipped for these flights; the fact that each machine carried a British certificate of airworthiness is sufficient evidence that their airworthiness and reliability had been thoroughly demonstrated. But the point I want to make is that the fact that it was possible to undertake flights of such magnitude and with passengers of such importance within a few weeks of the completion of the prototype aircraft is a high tribute to the excellence and reliability of British design. I venture to say that such a thing would have been regarded as out of the question a few years ago.

But though the general quality of design has improved in this way, it cannot be said that there has been any striking advance in regard to those qualities other than safety and reliability which affect the balance sheet of the operating company. The general standard of performance is certainly somewhat better than in the early days of air transport, but the improvement made has been of a comparatively small order.

As regards the amount of paying load which can be carried per h.p. of the engines installed, it has not been possible to make any substantial advance, because, although the modern machines are more efficient in this respect, a good deal of the advantage gained has had to be sacrificed in the interests of safety and reliability. The Armstrong-Whitworth Argosy is an example of a modern machine which, although provided with three engines and all the equipment now demanded, can carry a full 4 lbs. of paying load per h.p., a figure which is at least up to the standard of any previous passenger carrying machine of British design.

It is, however, in the direction of reliability that a real advance has been made, and this improvement in reliability has gone a long way, but not the whole way, towards the achievement of safety in air transport.

Sir Sefton Brancker, in the paper to which I have referred, made an analysis of the various risks in air transport, and a consideration of these risks in relation to the accidents which have occurred shows, I think, that there are only three serious risks in present-day air transport, namely, those arising from:—

(1) Lack of complete reliability in the power plant.
(2) Bad visibility.
(3) Inherent aerodynamic defects in the design of present-day aircraft.

The attention of designers and operators has been mainly concentrated on the first two of these problems for the reason that they are not so difficult to solve as the third one. It has been held that provided only highly skilled pilots are employed and provided aircraft are made so reliable that forced landings away from aerodromes need not be considered, the operation of aircraft in any normal weather will be quite sufficiently safe. There remains the problem of overcoming the risks involved in conditions of bad visibility, and considerable advances have already been made towards the solution of this problem. My own view is that real commercial success in air transport will not be achieved until the third problem, namely, the aerodynamic one, has been satisfactorily solved, because only then will it be possible to demonstrate that the risks associated with flying in the minds of the general public have been completely overcome. In saying this I do not mean to imply that air transport as it is operated at the present time is dangerous. It seems to me that the statistics published, which are available to anyone who cares to study them, show that British air transport has reached a standard of safety which compares very favourably with that of any other means of transport, but I do not think that the general travelling public understands that this is the case.

This brings me to a point where it is desirable to mention the important difference between air transport for the conveyance of passengers and air transport for the conveyance of mails and goods only. European air services are nearly all passenger and goods services, and in the case of the British lines between London and the Continent, the conveyance of passengers is an essential part of the programme. In the United States, on the other hand, the main air lines are run exclusively for the conveyance of mails, the geographical situation being such that mail services can be run on a useful and perhaps even profitable basis. The effect on design of this difference in the form of traffic has been a very striking one. I do not mean merely that passenger-carrying machines must provide a large cabin space and accommodation for the passengers, but that the conveyance of passengers has demanded a very much more rapid development in the direction of safety. The fact that British services have undertaken the conveyance of passengers has meant that the operating companies have from the start appreciated the importance of making the services as safe and reliable as possible. This has had a very marked effect on the design and equipment of aircraft, and also on the organisation of routes and the system of maintenance and inspection. The fact that passengers have been carried has ensured the maximum possible publicity for the occasional air transport accidents which have occurred in this country, and this publicity has, no doubt, had a salutary effect; though I do not mean to imply that the various companies which have operated in this country would not have been fully alive to their responsibilities to the public without such stimulus. It is not the publicity given to air transport accidents which is the serious factor affecting the volume of traffic, because such accidents have been so rare; it is the fact that the public is being constantly reminded of the dangers of flying in general by the reports of accidents which have been occurring with such lamentable frequency. Every time the Press announces a fresh accident, the general public receives another shock, and I do not think there is any doubt that these accidents have had a most damaging effect on the development of air transport.

I am not suggesting that every effort is not being made to prevent these accidents. I am well aware that every accident which occurs in this country is most carefully investigated by the responsible authorities, and that the information derived from such investigations is applied to the full extent possible with a view to preventing repetitions of such accidents. The causes of accidents are varied and often obscure, but the majority of accidents are directly or indirectly attributable to the basic fact that the aerodynamic qualities of the present-day aeroplane are nothing like good enough.

But the fact remains that air transport is suffering heavily from the accidents which are so constantly occurring in other branches of aviation, and it is to be hoped that the Press, which has done and can do so much to help commercial aviation, will use every possible effort and opportunity to bring home to the public the vast difference which there undoubtedly is between the standard of safety in air transport and that in other branches of aviation. Personally, I believe that so long as flying accidents are occurring generally, so long will the travelling public continue to be shy of travelling by air, and that for this reason the ultimate future of air transport depends on the solution of the problem of making aircraft aerodynamically safer.

In considering the psychological effect of flying accidents on the travelling public, one has to remember that we live in an age of such rapid progress that the standard of safety, reliability and comfort demanded by the public is continually being raised. Nothing but the very best obtainable is good enough. There is the same tendency in all forms of transport. Railway companies are faced with the necessity of continually improving the design of their rolling stock because the travelling public is not satisfied with the standard which was accepted a few years ago. The same is the case in motoring; the standard of safety, reliability and comfort of the cheapest motor-cars of to-day is far higher than

that of the most expensive and luxurious cars of the earlier days of motoring. The Rolls-Royce of to-day is the Ford of to-morrow. The standard of safety already achieved in air transport is very high in comparison with that of the early days of air transport, but it will have to be raised to an even higher level in order to meet the demands of the travelling public.

I have endeavoured to show how passenger traffic has stimulated technical progress in British air transport and will now briefly refer to the situation in America, where air transport has been confined to mail services. During a recent visit which I made to America I had the honour of attending a luncheon which was addressed by Colonel Henderson, President of the National Air Transport Corporation of America. In the course of an extremely interesting address on the subject of American air transport, Colonel Henderson explained how American air transport differed from European air transport. There are two essential differences; firstly, that in America night flying has been developed and established as an essential part of air transport operations, and secondly, that American air transport does not cater for passenger traffic. The American view is that commercial transport cannot pay unless night services are included, and having regard to the geographical situation there can be no doubt that this view is a sound one from the American point of view. With regard to the transport of passengers, Colonel Henderson considered that the time has not yet arrived when flying is sufficiently safe to justify the transport of passengers, and that in any case the transport of mails is a far more promising commercial proposition.

Everyone concerned with air transport must have the profoundest admiration for the determination with which night flying has been developed in America, but I do not think it could be fairly claimed that technical progress in America in regard to the design and equipment of commercial aircraft has been so rapid as in Europe. This is illustrated by the fact that in the trans-Continental mail service only single-engine machines are used, and some of these are of designs dating back to the days of the war. These machines make the journeys by night as well as by day, and strangely enough they are not even provided with wireless equipment. As you are all aware, a vast amount of research and development in regard to wireless has been carried out in America, and there is no logical reason for these night-flying machines being without wireless equipment except that the demand for such equipment has not been sufficiently insistent. To my mind this is almost entirely due to the fact that passengers are not carried. There is a vicious circle and I venture to think that technical progress in America would be accelerated if the transport of passengers were undertaken.

Coming now to a closer examination of the factors in aircraft design which affect this question of safety and reliability, I think it must be admitted quite candidly that the attention of designers and operators has been mainly concentrated on the attainment of greater reliability. So far as the aerodynamic features of present-day commercial aircraft are concerned, there has been progress, but nothing of a very fundamental nature. The general controllability of the modern British aircraft is probably distinctly better than that of the earlier types, but while a large amount of valuable research work has been carried out in regard to controllability at and below the stalling speed, it has not yet been found possible to apply the results attained in actual practice. Thus, although a considerable improvement in regard to safety has been achieved, it must be admitted that this greater safety has been achieved mainly through the attainment of greater reliability.

I will therefore proceed to deal with the more important developments in British aircraft design affecting reliability.

Single-Engine and Multi-Engine Aircraft

I do not propose to deal in any detail with the old and somewhat hackneyed controversy as to the relative merits of single-engine and multi-engine machines.

I think it must be generally admitted now that this problem has solved itself, at any rate so far as passenger transport is concerned. The single-engine machine held its own in British air transport for a number of years, and its record for reliability was certainly a very good one. But whatever the virtues of single-engine machines may be, it cannot be denied that there has always been and will always be a possibility of engine failure, which in the case of a single-engine machine necessitates immediate landing whatever the nature of the country over which the machine is flying. No matter how reliable the power plant may be made in the future, it would be impossible to persuade the travelling public that the single-engine machine can give them the maximum possible degree of reliability. In the earlier days of British air transport, the single-engine machine and the twin-engine machine were about equally represented, and they fought out the battle for supremacy until the twin-engine machine finally established itself as the safer proposition. If it has ever been seriously claimed that a twin-engine machine loaded with a full commercial load can maintain its height on one engine, that claim has been an exaggerated one. There are twin-engine machines which are capable of flying on one engine, but they do not carry sufficient load to meet commercial requirements. The greater safety of the twin-engine machine in its present form lies in the fact that it can glide for a greater distance in the case of one engine failure than can the single-engine machine. Since the advent of the three-engine machine, with which I shall deal later on, the twin-engine machine has come in for a considerable amount of criticism owing to the fact that it cannot actually maintain height with a full load on one engine. There have, of course, been cases where twin-engine machines operating on the Continental lines have been forced to land in unfavourable circumstances, but on the other hand there have been a number of cases where the second engine has made all the difference and enabled the machine to land perfectly safely on an organised aerodrome, or even to continue its flight to its destination. It is only fair to take into consideration the exceptionally bad weather conditions which prevail on the British routes. During the winter months particularly, the conditions are frequently such as to make it impossible for the pilot to fly at a height of more than a few hundred feet from the ground. In the event of an engine failure under such circumstances, it cannot be expected that the pilot will be able to reach an aerodrome unless he is within a few miles of such aerodrome. On the other hand, whenever it is possible for the pilot to fly at a height of, say, 3,000ft., the pilot can be reasonably certain of being able to reach a good landing ground in the event of one engine failure. The margin of safety is far greater than in the case of single-engine aircraft. It may be useful to examine the question as to what may be reasonably expected of a twin-engine machine in the event of one engine failure.

Let us consider the case of a twin-engine machine with a total weight of 13,500 lbs. and fitted with two water-cooled geared-down engines, developing a total of 850 h.p. at full throttle and maximum revolutions. It may be assumed that the thrust horse-power available at the maximum speed will be about 660 or 77·5 per cent. of the maximum b.h.p. of the engine, but as the air speed is reduced, the thrust h.p. available falls off very seriously partly owing to the reduction in r.p.m. of the engines and partly to the loss of propeller efficiency. Let us first consider the case where the machine is climbing at full throttle. The minimum thrust h.p. required to keep this machine in the air will be about 270 or 32 per cent. of the maximum b.h.p. of the engines, but at the low air speed at which this occurs the loss of thrust h.p. available will be so great that it is more efficient to climb at a higher speed. The best climbing speed will be a compromise speed considerably above the minimum flying speed; in the case under consideration it may be taken as about 1.4 times the minimum speed. At this climbing speed the thrust h.p. required to maintain height will be about 315, or in other words, more than 5 per cent. of the maximum b.h.p. of the engines will be wasted by climbing at this higher speed. Considering now the

thrust h.p. available, it will be found that the b.h.p. of the engine has fallen by about 8 per cent. owing to the reduction in r.p.m., and that the efficiency of the propellers has fallen to about 68 per cent., so that the net thrust h.p. available is only 530 or 62.5 per cent. of the maximum b.h.p. of the engines. There is thus a balance of about 215 h.p. available for climbing, and this will result in a rate of climb of 525ft. per minute. In the event of one engine failing, the machine will be flown under conditions which are closely similar to the climbing conditions. The machine will be kept at approximately the best climbing speed, when the thrust h.p. available will be about 265. The thrust h.p. required to maintain height will be increased by the extra drag of the stopped engine and by the drag due to setting the rudder over. The h.p. absorbed in this way will amount to about 25, so that the thrust h.p. required to maintain height will be 340. There is thus a deficiency of some 75 h.p., which will result in the machine losing height at about 185ft. per minute. Assuming that the height at which the engine failure occurs is 3,000ft., the pilot has sixteen minutes in which to reach a landing ground. The gliding range would be about 18 miles in calm air, and 22 miles with a wind of 20 m.p.h. allowing for the final turn into wind. In the case of a similar single-engine machine of the same total weight, h.p., etc., the rate of descent in case of engine failure would not be less than 800ft. per minute. This gives the pilot $3\frac{3}{4}$ minutes from 3,000ft. and a range of four miles in calm air or $4\frac{1}{2}$ miles with a twenty-mile wind. In both cases, of course, the rate of descent is apt to be increased in bumpy conditions, but the figures give a fair comparison of the relative merits of the two machines considered.

The twin-engine machine considered above is of course fitted with ordinary propellers of constant pitch. If, now, we consider the use of variable pitch propellers, we find that a great improvement can be effected. There are two important items of wasted h.p. which can be recovered, viz., the loss due to the reduction in r.p.m. of the engine and that due to flying at a speed higher than that at which minimum power is required. In the example taken, these amounted to 8 per cent. and 5 per cent. respectively of the maximum b.h.p. of the engines. The position will thus be that the thrust h.p. required to maintain height at climbing speed will be reduced to 270, while the thrust h.p. available will be increased to 595, assuming a propeller efficiency of 70 per cent. With both engines running the rate of climb will now be nearly 800 feet per minute, as against 525 feet per minute before. With one engine out of action the thrust h.p. required and the thrust h.p. available will be just about balanced, so that the machine will just be able to maintain height.

Thus it will be seen that although the present-day twin-engine commercial machine cannot be expected to maintain its height on one engine, yet by the comparatively simple expedient of using variable pitch propellers in conjunction with geared-down engines there is a prospect that we can make our existing twin-engine machine capable of maintaining height with one engine completely out of action. At the present time a number of British firms are engaged in the development of variable pitch propellers, and it appears probable that we shall not have to wait long before an efficient and suitable variable pitch propeller is available. As soon as such a propeller is available the position of the twin-engine machine will be considerably altered, and it is quite possible that it will have a new lease of life. My argument has been based mainly on the question of reliability, but I am not losing sight of the advantage gained in regard to rate of climb with both engines running.

Before leaving the subject of the twin-engine machine I would emphasise the fact that the value of reduction gears is particularly important in the case of such machines. The later types which have been put into service by Imperial Airways are fitted with radial air-cooled engines which, of course, have very great advantages, not only in regard to their lightness and accessibility, but also in regard to their cost of maintenance. Although the introduction of variable

pitch propellers would mean that such radial engines could be used to very much greater advantage, they will not be really suitable for use in twin-engine machines until they have been fitted with reduction gears. The advantage which can be derived from the use of variable pitch propellers can only be partially realised in the case of these ungeared engines running at 1,800 to 1,900 r.p.m. at their maximum power. I do not wish to enter in detail into the old controversy as to whether the use of reduction gears in the engines for commercial aircraft is justified. I merely point out that in using ungeared engines running at such high revolutions we are losing a very substantial percentage of the available power which we need so much in taking off and climbing, and in the event of engine failure. This loss of thrust h.p. may be anything up to 10 per cent. of the maximum b.h.p. of the engines. The only serious objection to the use of reduction gears is, I think, the extra noise entailed, and it is a matter of opinion whether this extra noise outweighs the gain in power at low air speeds which the use of reduction gears would bring. My own view is that safety and reliability are more important than any other consideration in air transport, and therefore that this extra noise, if indeed it is unavoidable, ought to be faced. I would also point out that high speed propellers are extremely noisy and that for this reason the use of reduction gears would result in a nett reduction in noise.

I have endeavoured to show that the twin-engine machine, which in many quarters is regarded as almost a thing of the past in view of the advent of the three-engine machine, has greater possibilities in regard to reliability than is often supposed. However, there can be no doubt that the three-engine machine is essentially much more reliable than the twin-engine machine. I do not myself believe for a moment that now that the three-engine machine has come into service, there will be any reversion to machines with less than three engines.

In the case of the twin-engine machine, I pointed out that if one engine fails the effective power loading is much more than doubled. Similarly, in the case of the three-engine machine, a failure of one engine raises the effective power loading by more than 50 per cent., but in the case of the three-engine machine the loss of power due to the reduction in speed and loss of propeller efficiency is not quite so formidable, because there should be sufficient power left to enable the machine to fly at reasonably high air speed. When we consider the question of climb, however, we find that the loss in effective power is again very serious, and for this reason the rate of climb of three-engine machines when one engine is out of action is disappointing.

In fact it is not to be expected that all three-engine machines will have a rate of climb with one engine out of action. Let us consider the case of a three-engine machine designed to meet the performance requirements for the European services and carrying the heaviest commercial load consistent with those requirements. Such a machine fitted with geared down engines should have a small reserve of power with one engine out of action, but if fitted with ungeared engines it will have to be of good aerodynamic design to be able to hold its height. I do not think it will be worth while to examine a specific case in detail as the example which I quoted to illustrate the position in regard to twin-engine machines will serve the purpose. If in that example we had taken a loss of one third of the thrust h.p. available at climbing speed instead of one half, we should have a case closely resembling the case of a three-engine machine in which one engine fails. We should have to make a smaller allowance for the h.p. absorbed by the dead engine as the power per engine would be relatively smaller, and bearing this in mind we should find a small margin of power available, about 20 h.p. beyond that required to maintain height. The same hypothetical three-engine machine fitted with ungeared engines would not be able to maintain height on two engines. The twin-engine machine taken was not, however, of up-to-date design, and a rather better performance can now be expected. A modern three-engine machine with ungeared air-cooled engines

can be expected to maintain height on two engines, but it will be apparent from the example taken that ability to climb on two engines is only to be expected in the case of a three-engine machine of considerably better performance than that required for the European services. The de Havilland Hercules is an example of such a machine. This machine, it will be appreciated, was specially designed in order to meet the particular atmospheric conditions prevailing on the Cairo-Karachi route. The low densities encountered on that route during the hot season, combined with the high altitudes of some of the aerodromes, are such as to demand a machine of considerably better performance than that required in the machines operated in N.W. Europe. In order to achieve this high performance it has, of course, been necessary to sacrifice a certain amount in regard to paying load, but without such sacrifice the service could not have been operated with the degree of safety and reliability which is now assured.

Although these modern three-engine machines represent a great advance in regard to safety and reliability, their virtues would be enormously enhanced if their respective engines were fitted with reduction gears and variable pitch propellers. A combination of these two improvements would revolutionise the performance of such machines.

Before leaving the subject of multi-engine machines and their effect on the safety and reliability of air transport, I will cast one fleeting glance towards the future. I have endeavoured to show that the three-engine machine has in fact been a great step forward in regard to reliability and safety.

But it appears to me that the three-engine machine is only a stage in the development of the multi-engine machine. From the point of view of reliability the four-engine machine is better than the three-engine machine, for although there is a theoretical increase in the probability of engine failure as the number of engines is multiplied the risk of more than one failure occurring during a flight is in practice greatly reduced because as the number of engines is increased failure of one will cause less strain on the others. But if the four-engine machine has advantages over the three-engine machine, the five or six-engine machine has greater advantages over either. A five or six-engine machine employing air-cooled engines with reduction gears and variable pitch propellers appears to me to be the logical development which must come. Such a machine will represent almost absolute reliability, for it will be able to keep flying even with two engines out of action, and the failure of more than two engines during one flight is remotely improbable. Moreover, it will retain this degree of reliability when carrying the maximum commercial load with which it can safely take off. There are, of course, objections to a multiplication of the units of the power plant, but none of these appears to me to rank in importance with the advantages gained. There is also the fact that the economic size of aircraft is limited, but the indications are that we have not yet reached that limit, and in any case the multi-engine argument holds good whatever the actual size of the aircraft. At the present time the volume of traffic is not sufficient to justify any further increase in size, but I believe that as safety and reliability increase the traffic will increase to such an extent that larger sizes will be justified. I am not advocating any hasty policy in regard to the evolution of the multi-engine machine; we must first have our reduction gears and our variable pitch propellers. But I am confident that we shall get these, and that sooner or later we shall have five or six-engine machines.

I am afraid that I have dealt at such length with the questions of general policy in regard to design that I shall only be able to refer to the more practical aspects of my subject in a very cursory manner. I shall also have to omit any special reference to design features of seaplanes or flying boats. Practically the whole of my foregoing remarks are applicable to marine aircraft as much as land aircraft, but I would add one general comment on the future prospects for marine types. It seems to me personally that the advent of the really reliable

aeroplane will greatly reduce the scope and utility of the seaplane and flying boat. If it becomes possible to fly from point to point with almost absolute reliability there will be little reason for employing marine types, which have distinct disadvantages from the operating point of view, except of course in certain special cases. I am inclined to believe that most of the long distance air routes will be operated with land type aeroplanes, and that the use of marine types will be mainly confined to local and special services for which such types will have particular advantages.

Progress in Regard to Reliability of Power Plant

The outstanding development in this direction during the last few years has been the world-wide movement in favour of the air-cooled engine for commercial work. The air-cooled engine has certain definite advantages in regard to reliability, viz. :—

(i.) Elimination of defects in the water cooling system, which have been one of the most prolific causes of trouble.

(ii.) Greater accessibility, which facilitates inspection and maintenance.

Although it is only comparatively recently that air-cooled engines have come into general service for air transport work, there is no doubt that these particular advantages have already been realised in a marked degree, but sufficient experience has not yet been gained to provide reliable statistics. Air-cooled engines have, of course, in common with water-cooled engines, other weaknesses, and I am merely stating that they have an advantage in the two particular points mentioned.

Apart from this definite development progress in regard to reliability of power plants has been mainly in the direction of the gradual elimination of the detail weaknesses in the engines themselves and in their installations which are potential sources of trouble. Most of the causes of engine failure—at any rate in the case of engines which have passed through their apprenticeship in commercial aviation—are traceable to comparatively minor defects. Such defects are not confined to the installation; they occur sometimes in the engines themselves, due to some detail weakness in design which may not have revealed itself during several years' service of the type. The evolution of the really reliable aircraft engine installation has been a long and laborious process, but great progress has undoubtedly been made during the last few years; the contribution in this direction of the Engineer Superintendent of Imperial Airways and his staff at Croydon has been a very important one.

There are still a number of points in the design of engines and their accessories which are far from satisfactory, including such important items as magnetos, sparking plugs, engine instruments, etc., and engine manufacturers would do well to remember that an engine is not reliable unless its accessories are reliable, and to take action accordingly.

Controllability

In regard to this most important question, I can only say that during the last year or two it has been receiving much more attention than ever it did before. The general standard of controllability in the latest types of commercial aircraft is distinctly above that of the earlier machines. Greater attention has been paid in particular to control at low speeds, and this has been of special importance in the case of the large three-engine machines now in service. By very careful balancing of the control surfaces it has been possible for designers to provide sufficient control for these large machines, but in my view we have come to the end of our tether in this respect. Any further increase in size of commercial aircraft will, I think, necessitate the use of relay controls operated by servo-motor. So far as this country is concerned there has been no practical

application to transport aircraft of the results of the Aeronautical Research Committee's work on the Handley Page Slot and Aileron Control. There are several reasons for this; in the first place no operating company can afford to experiment on a large scale unless specially subsidised for the purpose; secondly there has been no practical demonstration of this form of control on a full-scale commercial machine from which an accurate appraisal of its merits (aerodynamic and mechanical) could be made; and thirdly, at the time when contracts for the several new types were placed the time for the practical application of this form of control had hardly arrived. Slot and aileron control can only be satisfactorily incorporated in a new design; its application to existing machines would involve considerable practical difficulties. The placing of a contract for a new type of commercial aircraft is, unfortunately, a somewhat rare event, but I can assure you that a watchful eye is being kept on this and other developments for the improvement of controllability, and that the importance of the question is fully appreciated. Amongst the "other" developments I would include the good control achieved by Mr. Fokker in his thick wing monoplane types. I shall refer again to this question of controllability in the general remarks at the end of my paper.

Structural Strength and Detail Design

It is refreshing to come to a department of aircraft design in which a state bordering on perfection has been reached, and in which no further improvement is required. I hasten to explain that this happy state of affairs does not apply to both the subjects included in the heading of this paragraph, but only to the former. The standard of general structural strength of British commercial aircraft is a very high one; indeed so far as I know there has never been a structural failure in the air of a British transport machine. The high standard of load factors specified, an efficient Airworthiness Department, good design and workmanship, close inspection and careful maintenance, have all contributed to this satisfactory state of affairs. But when we come to the question of detail design we find, of course, that there is room for a good deal of improvement. Actual failures of detail parts are now comparatively rare, but there has sometimes been a tendency amongst designers towards cheese-paring in regard to their detail parts and fittings in order to save weight. The result of this has been that in course of time, through fatigue or wear, failures have occurred; such failures have very rarely been serious enough to endanger the structure as a whole, but they have often necessitated expensive replacements.

There are certain parts of a commrcial machine which must necessarily be subjected to constant knocking about and wear, and with all respect I say that designers have not yet appreciated the importance of robustness and local strength to meet loads other than aerodynamic loads. The designer is inspired by the laudable desire to save weight, but excessive zeal in this direction sometimes results in modifications involving more weight than ever was saved in the original design.

I think it is true to say that the strength of detail parts and fittings in commercial aircraft is not up to the standard of strength of the main structural members; at any rate the latter do not fail, whereas trouble is sometimes experienced with the former. I am not sure that we should not have a sounder aircraft if we slightly reduced the main load factors and spread the weight saved over the fittings and detail parts of the structure. I suppose that such a suggestion will be considered very heretical; but the fact remains that we have never had a main structural failure, whereas we have had failures of fittings, which, if undetected, could have resulted in structural failure. I hope these remarks will not be misinterpreted; I do not want to see the slightest reduction in overall strength, but I do not feel sure that we are getting the maximum overall strength for the weight of the structure.

Instruments and Equipment

I had intended to deal briefly with this subject and to include with it some notes on pilot's accommodation and view. In order to keep the paper within reasonable limits I shall have to omit these sections, confining myself to the remark that while the view provided for the pilot is generally satisfactory for present requirements, I do not think the present standard will be good enough in the future when there are more machines in the air. At present the pilot and wireless operator sit side by side, the pilot being provided with a good view to port and a fair view to starboard, this arrangement being favoured by the majority of pilots. In a few years' time I think the pilot will have to be provided with an uninterrupted view forwards and to both sides, but I will not embark on a discussion as to how this can best be done.

Fire Prevention

I shall have to omit this subject also. Provided proper precautions are taken, the risk of fire is now fortunately so slight as to be almost negligible. Fire is liable to break out after a very serious crash, but the elimination of this risk presents great difficulties. The prevention of crashes must be the first concern of aircraft operators.

I have now come to the end of the more important factors affecting safety in the design of aircraft for transport purposes. I had intended to proceed to a section on design features affecting operating costs, and then to another on the comfort of passengers. However, in attempting to deal with the safety aspects of design (quite inadequately I fear) I have allowed myself to dilate to such an extent that it will be impossible to include these two sections in the present paper. To embark on the former at this late stage would be a hopeless task, while the latter would be redundant in view of the illuminating address on the same subject which we have so recently had from Air Commodore Weir.

General Air Service

There are so many diverse commercial uses to which aircraft have been put, and so many possibilities for future development, that it would appear at first sight impossible to lay down any general principles in regard to the design of aircraft for commercial purposes other than regular air transport. It will be found, however, that these diverse forms of air service fall into four main groups, for each of which particular design features are required.

1 *Air Survey and Exploration*

In this group the following classes of air service may be included :—

Air Survey and Photography.
Exploration and Reconnaissance.
Forest Patrol
Coastguard and Border Service.
Crop Protection and Pest Destruction.
Fish-spotting.

The requirements in aircraft for these different classes are by no means identical, but it will be found that they are generally similar. There are two essential features which are common to the requirements of all of these classes, namely, a high degree of reliability and uninterrupted view for the pilot. In the case of nearly all of these classes a high performance is essential. There are many other features which are required to a greater or less extent in each case. I do not propose to consider the requirements of each class in detail, but to take the particular case of the air survey machine as being the most important in the group. The more important requirements for a survey machine may be summarised as follows :—

(i) The pilot must have an unrestricted view ahead and to either side.

(ii) The machine must have a very high degree of reliability; in fact, it must be practically immune from forced landing. Many of the regions in which air survey can be most usefully applied are such that a forced landing would mean disaster to the aircraft and its crew.

(iii) The machine must be able to operate at a height of 15,000ft. or more, at which height it should have a cruising speed of not less than 100 m.p.h.

(iv) It must be adaptable for use on land or water, according to the circumstances of the particular survey.

(v) It must be able to land safely on a small landing ground or stretch of water.

(vi) It must be stable, but sensitive to its controls.

(vii) It must have fuel for about six hours. When suitable weather occurs, full advantage must be taken of it.

(viii) A crew of two and photographic gear to a total weight of about 1,000 lbs. must be carried. The machine should be as small as possible having regard to the load and the other requirements. There is no scope for the very large machine in air survey work. The stowage and mounting of photographic gear presents no serious difficulties in a small machine specially designed for the work.

(ix) Robustness and accessibility are essential having regard to the conditions under which the machine will be operated.

It will be seen that the requirements are widely different from those for a transport machine, and nothing but a specially designed machine will meet the case satisfactorily.

Up to the present time survey work has had to be carried out on machines which have been adapted as far as possible to meet the requirements, but there is every prospect that with the rapidly growing demand for air survey the specially designed survey machine will soon make its appearance.

It will be seen from the requirements summarised above that the single-engine machine can be ruled out on the grounds of reliability, and that a multi-engine machine of very high performance is called for. On the other hand, the load to be carried is small in comparison with the loads for which transport machines are now designed.

The requirement in regard to pilot's view suggests strongly the desirability of using a twin-engine machine, but such a machine must be provided with a very high reserve of power, so that it can cruise comfortably with one engine completely out of action, and thus return to its base without having to overtax the remaining engine. The twin-engine machine appears indeed to offer the best solution of this problem, and a design for such a machine to a specification based on the above requirements has already been prepared.

Referring again to the other classes of air service which I have grouped with air survey, it will be seen that the air survey machine is the only one which is called upon to work at great heights. On the other hand good speed range, good ceiling and good reliability are closely allied, and it will be found that the ideal survey machine, suitably adapted and equipped, will be very nearly the ideal machine for these other classes of air service.

2 *Transport of Plant and Machinery*

In the second group I would place the application of aircraft to the transport of heavy goods, such as plant and machinery, in undeveloped countries. In

countries where reasonably good ground transport is available there is obviously no scope for air transport of this kind. In many parts of the world, however, there are enormous possibilities for such transport. Take, for example, the case of oilfield development. It is quite possible to transport by air the entire equipment necessary for sinking a test well from the base to the location, and the cost of such transport may be far less than that of any other means of transport. Where the country is broken the construction of a special road may be involved, and it must be remembered that such road may or may not have any future value; it depends on the skill and to some extent, I understand, on the luck of the geologist.

For such classes of transport a heavy load carrier of low performance and ample capacity is required. An experimental single-engine machine of this class is under construction for the Air Ministry at the present time. This machine was originally intended to carry 8½ lbs. of paying load per h.p. of the engine, but I am not sure whether this high figure will be realised in practice. While some very interesting data should be obtained from this machine, I believe myself that a multi-engine machine is required for this class of work. The requirements in regard to reliability are perhaps not so great as in the case of regular air transport, but a machine which is to tackle seriously such transport propositions as the one I have mentioned must not be liable to forced landing when carrying a valuable cargo of engineering plant over rugged and inaccessible country.

3 *Taxi-Flying*

In the third group of air service activities I include taxi-flying and all forms of private hire flying. Taxi-flying has not been developed in this country to anything like the extent that it has in America, but even here it has been established as a definite branch of commercial aviation. The requirements for taxi-flying are not quite so exacting in the matter of reliability as those for regular air transport, as the operator has more discretion in regard to routes and weather, and is not tied by any scheduled time-table. Therefore there may be more scope for the single-engine machine for this class of work. Whatever the type of machine used, it must be comparatively small, cheap to operate and maintain and of sufficient performance to enable it to beat any other means of transport even on comparatively short runs. If adverse winds and road journeys to and from aerodromes are taken into consideration, it will be seen that a cruising speed of something like 100 m.p.h. is required. Although the single-engine machine has a chance of holding its own in this class of work I believe that taxi-flying operators will follow the general movement towards reliability, and adopt the small three-engine machine as their type.

4 *Club and Private Flying*

With club and private flying I would group school flying, joy-riding and the various miscellaneous uses other than transport to which aircraft are put. Considerations of simplicity and cheapness commend the single-engine type for such classes of flying. The design of aircraft suitable for such purposes does not call for comment in this paper, except in regard to the general question of safety. The outstanding requirement for aircraft in this group is greater aerodynamic safety, partly because it is through this class of flying that the flying sense of the public can best be developed and partly because a lower standard of piloting is to be expected.

General Review

Having now referred to the main branches of commercial aircraft design, I will conclude by briefly reviewing the general situation from a rather more

detached point of view. I have endeavoured to emphasise as strongly as I could the importance of safety, because I believe that the one factor which is seriously retarding the progress of commercial aviation is the need for greater safety in all forms of flying. I have made it quite clear, I think, that I do not myself consider air transport, as it is now being operated, to be dangerous in comparison with other means of transport, and I maintain that published statistics amply confirm this view. But flying in general has not reached the degree of safety which has been achieved in air transport, and it is the lack of confidence in flying in general which is hindering the development of commercial aviation. I am looking at this question from a purely commercial point of view, because the primary consideration in commercial aviation is whether it can be made to pay. In dwelling so much on the importance of safety I may have appeared to lose sight of the commercial aspect of the question, but I can assure you that this is not the case. My whole argument has been based on a belief that the surest and quickest way to commercial success in air transport is by establishing public confidence in flying.

I have devoted the bulk of my paper to the question of reliability because that is the direction in which progress towards safety has been chiefly made in air transport, but I pointed out the importance to commercial aviation of eliminating or reducing the fundamental aerodynamic risks of flying in general. In order to explain what I mean by "fundamental aerodynamic risks," I will quote, if I may be excused for doing so, a brief summary of the aerodynamic weaknesses of present day aeroplanes which I made last year:—

(1) The landing speed is far too high and the length of run after landing is too great.

(2) The gliding angle is too flat, making the approach to a given spot for landing too difficult.

(3) The length of run required before taking off is too great.

(4) The angle of ascent after taking off is not great enough.

(5) If the aeroplane is stalled, it becomes unstable and at the same time control is lost.

Formidable as the problems involved in overcoming these essentially dangerous features undoubtedly are, there are prospects that some of them, perhaps all, will have been successfully tackled within the next few years. In this country we have recently had some most important demonstrations as to the possibility of solving some of these problems—the Slotted Wing, the Autogiro, the Pterodactyl—and the future is hopeful because attention has been focussed on the subject. I think you probably all know of the decision of the Trustees of the Daniel Guggenheim Fund for the Promotion of Aeronautics to direct their policy primarily towards the attainment of greater safety in flying. With a view to encouraging definite effort in this direction they have decided to hold an "Open International Safe Aircraft Competition" during the next few years. As the representative of the Fund in England I had hoped to be able to make an announcement to you this evening in regard to the details of this competition, but unfortunately the date of my paper has come just too soon for that to be possible. However, I can tell you that the object of the competition will be to achieve a real improvement from the safety point of view in the aerodynamic characteristics of heavier-than-air craft, without any serious sacrifice of the good practical qualities of the normal present-day type, that the competition will be open to competitors of any nationality, and that very substantial prizes will be offered. I think there is every reason to hope that this competition will have very valuable results, not only in the production of actual designs of greater aerodynamic safety, but in demonstrating the great progress which has been made in recent years in the direction of safer flying.

Discussion

Mr. F. Handley Page: In opening the discussion, I am sure that you would like me to express the thanks of us all to Major Mayo for the paper to which we have listened this evening.

There are one or two things in which he is wrong in his paper, but they are quite minor things. First of all, one of the *good* machines which he mentioned was built in 1921 and not in 1922, so that instead of five years of life it has had six years, which is all the more to the credit of the Operating Company!

There is one effect which Major Mayo has referred to that must be emphasised, and that is the adverse effect of the number of accidents in military flying. I do not mean that military flying is of a lower quality than civil, but that there are manœuvres and stunts in the course of which accidents are likely to occur. The unfortunate effect of this on the public is that they, not appreciating that the military pilots have in many cases not long learned to fly and have very difficult tasks to perform, imagine that they—the public—run the same risks when flying in commercial machines piloted by men of long training and years of experience. Less and less accidents occur in commercial flying, but the adverse effect of military accidents undoes the good effect on the public mind.

With regard to night flying, and American experience of this, I only hope that Major Mayo has some programme in mind for beginning it in this country, because I feel that night flying and its successful operation is one of the most important things in commercial aviation. We are so hampered by the short hours of daylight in these parts of the world, and by bad visibility, that I do hope it will be possible to have night flying from England. When one attempts to fly to Italy or Vienna there is no saving of time if you use the aeroplane unless you can fly both day and night. One must have night flying in order to make any advance.

I agree with Major Mayo on the value of gearing. I am perfectly convinced that we shall never get the full paying load until we have geared air-cooled engines. The losses are so great when the tip speed of the propellers approaches that of sound that we shall never get the full advantage out of our air-cooled engines until we can gear them, and the advantages will be still greater when we also have variable pitch propellers. I dream of an aeroplane which will have a variable pitch four-bladed propeller of about 20 feet diameter for getting off and which during the flight could be changed to a nine feet diameter two-bladed propeller. There is a problem for the young aircraft designer. I really believe it is a problem that, solved in a limited measure, would certainly help commercial aviation greatly.

There is one thing against air-cooled engines that Mr. Walker referred to in his paper in *Flight*, and that is that the air-cooled engine does not seem always to give of its best. Its supporters would desire to see less falling off of h.p. on the climb—quite apart from the propeller efficiency if directly driven without gearing. Perhaps Major Mayo can give us some figures for comparison.

Major Mayo refers to marine aircraft and the probability of their scope and utility being reduced if we are able to develop a really reliable aeroplane. I differ from him in that respect. For marine aircraft we have landing places already prepared in existing harbours. We find a great number of advantages that we do not meet in aeroplanes; for instance, instead of aerodromes miles away from the centres of towns we can use rivers and reach the heart of the business centres with a great saving of time. In newer countries where there are no aerodromes there are wide rivers which seaplanes can use. Air survey is only possible in countries where rivers exist to which seaplanes can return. The marine aircraft will always have a definite sphere of action.

On the question of multi-engine aircraft, I am glad to see that Major Mayo is converted from his errors of 1923. He now agrees with the views of the paper by Mr. Savage and myself expressed at the International Air Congress held in London that year. Now that he is on the right path we may hope for developments. If five or six engines are used in commercial aircraft of the future the one certain thing is that breakdown will be assured. One engine is sure to break down. There will be increased complications and weight in the piping and engine mounting. When we have developed variable pitch propellers and geared-down engines we shall be able to return to the twin with the same measure of confidence as in the multi.

The essential thing is to ensure that you can alight safely if your engine gives out, and in regard to the five essentials given at the end of Major Mayo's paper for commercial aircraft, I am in entire agreement. In order to reach success in securing these essentials we ought to carry out the necessary researches as soon as possible.

With regard to fitting slots to machines already in existence, Major Mayo states that this cannot be done. I was not aware of that, but possibly he can tell us more about it. The statement is followed by a somewhat governmental expression ending with the words "that a watchful eye is being kept on this and other developments for the improvement of controllability. The importance of this question is appreciated." It sounds as though some apology was needed when, with the appreciation that he has of the necessity of fitting these things, the company with which he is connected has not done so. However, as he has been converted from single to multi-engined machines, I have hopes that he will eventually be completely converted in regard to the slot and aileron control, but I trust it will not take four years to carry out this second conversion, which I think is equally necessary.

Mr. M. L. Bramson: Major Mayo mentioned the variable pitch propeller, and one would very much like to know whether he intends these variable pitch propellers to be automatically controlled or controlled by the will of the pilot. In the latter case one must feel some pity for the pilot in dealing with six-engine machines when he will have to adjust the pitch of each engine in flight to the right value.

There is one point of query that I would like to raise with regard to the calculations which Major Mayo gave when referring to the performance of twin or three-engine machines when one engine has failed. He referred to the optimum flying speed. Actually, as the loads which such aeroplanes will be flying cannot be predicted, and as conditions vary with such things as whether the failure took place at the beginning or near the end of a flight, the optimum flying speed is a problematical figure. There is also the angle of incidence to be considered. Actually nobody knows at what angle of incidence he is flying, and that is an important point if he wants to fly efficiently. Major Mayo implies that he flies just at the optimum incidence. In actual practice he will not do so and the margin of safety will be lower than the calculations show.

There is on the European part of the Imperial Airways Service only one machine that is capable of flying after one engine has failed. Every man in the street, when he hears about three-engine aeroplanes, imagines that when one engine fails they can go on flying with two, and when the machine is flying to which this attribute does not apply, the company is taking money on false pretences. This is a Government-subsidised company and it is a serious matter. The man in the street thinks he is perfectly safe when one engine fails, and my opinion is that he is not. If the Government grants such a subsidy to a company to operate safely, that subsidy should be applied by the company to produce the safety.

Lieut.-Colonel J. BARRETT-LENNARD (*communicated*): Considering that the title of Major Mayo's paper is design, it is with great diffidence that I venture to speak. I am not a designer, and although at last I have it clearly fixed in my mind that there is a distinction between an aileron and an elevator, I am not sufficiently encouraged to even hope to become an aeroplane or engine designer.

Having made it clear that I am entirely ignorant of this very abstruse art, I venture to make some comments on design.

Major Mayo has very properly and aptly stressed the importance of safety and I hope I shall not be misunderstood if I say that while absolute safety may be attainable in aeroplanes, it may also be that the expense would be so great that it would never be brought into practical use.

We must remember that no form of transport is in practice immune from accidents—there are still railway accidents, there are still maritime accidents; we are all very conscious of motor accidents, in all of which failure of the material employed may be the main or contributing cause.

It is many years since the old 0/400 machines navigated the London-Paris route with a reliability and safety that was not at all bad.

As I have indicated, I conceive that there are possible improvements by design or re-design of aircraft and engines by which the factor of safety may be still further improved.

Without in any way minimising the importance of safety, I would point out that the long flights to India of the latest commercial aeroplanes show that while absolute safety is not attainable, we have already reached the point of safety without the absolute.

But quite frankly it does not appear to me that British designers and constructors have really considered the question of *cost*. Foreign designers and constructors seem to be more inclined to regard the question of cost when designing.

The two main factors of the cost of civil aviation are Capital Cost and Maintenance of Plant.

I would urge all those whose business is to ask for designs, as well as those whose business it is to design and construct, to accept that the elements of cost of construction and maintenance are as much factors to be considered as any purely aero-dynamical factor.

Otherwise there is a danger of killing the present rather weakly goose (commercial aviation) that lays the golden eggs (*i.e.*, orders for civil machines).

On the other hand, a wise and far-sighted policy might fatten and strengthen the bird.

The practicability of aerial transport is proved—reasonable safety is proved—what still requires proof is that commercial aviation is economically possible.

Years ago an authority stated that even then commercial aviation was possible without subsidy. It was not really so, nor is it so now.

But I am convinced that when aeroplanes and aero-engines can be bought and sold much more cheaply than at present, commercial aviation will be commercially successful. It will come, and I hope that British designers and constructors will be in the lead in this question of cost, although at present they would appear to be rather behind the rest of the world.

I am not expressing the views of my fellow directors of Imperial Airways, but I have the personal conviction that if the cost of commercial aeroplanes and engines were very substantially reduced we should be able to order them in tens where we now order in ones.

We see at the present day Germany planning an enormous development of aerial transport; France and Italy, too. That means that in the minds of far-sighted men, aerial transport is very definitely going to make enormous strides—may our country be in the van of progress in this direction, and the idea I

contribute to the problem is that the user and designer must add to the factors with which they deal—the factors of cost of construction and cost of maintenance.

At present the capital cost of the aerial plant to carry any given load is very greatly more than the cost of any other form of transport, even that of transport de luxe, such as yachts and motor cars.

The ratio of capital cost to paying load varies in the case of certain types of machines with engines in the service of Imperial Airways from £3 per lb. to £5 per lb.

Aeroplanes without engines: £1.8 to £3.2 per lb.
Engines alone per machine: £1.03 to £1.77 per lb.

Mr. C. C. WALKER: I agree so fully with most of what Major Mayo said that I have very little to say. Possibly, looking ahead, the five or six-engine machine does not appeal to one as the most satisfactory solution as it seems to bristle with difficulties. The engines cannot be put where they will not interfere with the aerodynamic qualities of the machine.

The other glimpses that Major Mayo gives us, of the superior qualities of the twin-engine of the future, are more alluring. If the twin-engine could fly with a good load on one engine, that would be a very real advance. The middle engine on a multi-engine machine has a very large body behind it and one does not get the full value from it.

Major Mayo includes crop protection and pest destruction among classes of air service. This is illegal here. We once secured a contract for this work, but were at once brought to book by a sharp letter from the Air Council asking us to explain our infraction of the regulations which deals with throwing things out of aeroplanes.

Captain F. TYMMS: With regard to the remark made by Mr. Walker, I was surprised to hear that spraying of crops by aircraft had been ruled to be illegal, and I would point out that the Civil Aviation Department is doing its best to encourage activities of this kind. The basis of the argument, I suspect, is the regulation that you may not drop anything out of an aeroplane without the permission of the Air Ministry. I should doubt whether the dropping of dust or spray from an aeroplane is covered by this regulation, but if it is, no doubt suitable steps can be taken to amend matters.

(*Communicated*): Two points in Major Mayo's excellent paper seem to have been dismissed with less consideration than they deserve. The first, the problem of fog, with certain consequent problems of design, is partly covered by Major Mayo in his remarks on variable pitch propellers. The second, the question of seaplane services, as pointed out by several speakers in the discussion, has led to a conclusion which will meet with little general support, particularly at a time when the design of commercial seaplanes is beginning to receive the attention which it has for many years lacked. The connection of night flying with seaplane services has received little attention.

An examination of statistics shows that the cause of the majority of cancellations or interruptions of scheduled air transport journeys in this part of the world is weather. "Weather" means bad visibility. The preponderance of this cause is so great as to make it the key to the whole problem of making air transport pay. It is no secret that the operations of Imperial Airways practically pay during the summer but fall far short of doing so in the winter. Why? Because the would-be passenger knows that he cannot rely on getting to his destination or even on starting if he decides to go by air, whereas he has a fair chance if he elects to go by surface transport. He knows that comfort and safety are not vastly different, winter and summer. When a passenger can go to Croydon with the same degree of certainty of getting to his destination as now he goes to Paddington to catch a train to Birmingham, then will air transport pay, but not till then. When all has been said about comfort and safety,

one has to face the fact that reliability, the most difficult of achievement, will produce the greatest reward.

This is something of a platitude. Everyone knows so well that bad visibility is the arch enemy, and it has been said so often, that one is apt to get into a resigned frame of mind about it and to accept it as an inevitable and insurmountable obstacle. The solution is in the hands of the physicist rather than the aeronautical engineer but, in a discussion of the problems of operation of commercial aircraft, one cannot afford not to put it in its rightful place—at the top of the list of unsolved problems—not only to obtain a true perspective of the whole, but because the continued statement of a problem serves to focus the attention which is necessary for its solution. Assuredly it will be solved, whether by infra red, electric, or some other form of radiation to which aqueous particles offer no obstruction.

When this problem is solved, the method of operation will inevitably change in such a way as to involve problems of design. Flight will then be carried out at a greater height. For almost every reason it must be. To fly at 100 m.p.h. within a few hundred feet of the ground, exposed to the danger of collision with surface obstacles and with other aircraft, whose pilots are equally half blinded, subjected to the bumps which the proximity of the earth's surface causes, and in conditions of depressing semi-darkness, can never be defended as a rational means of transport, and I believe will not be accepted as such by the travelling public.

Whatever the effect on the paying load, on the petrol bill and even on the time taken for the journey, air transport, in the not too distant future, will, in conditions of low cloud and fog, have to be carried out above the clouds. It may not always be possible. It may sometimes even be necessary to fly within the cloud, which is better than flying beneath it, but at a height of 10,000 feet, on a large number of days when passenger machines now go steeplechasing, they might fly in sunshine and steady air. Comfort follows from both, and coupled with Major Mayo's thesis that aeroplanes whose composite power plants will be absolutely reliable are now in sight, safety will also be improved. The problems of navigation are not serious. The problems of control have been overcome. The result will not fall far short of an equalising of traffic returns for all months of the year.

It is better to have a fleet of 15-seater machines carrying an average of 12 passengers throughout the year than a fleet of 20-seaters carrying 20 passengers in the summer and four or five only in the winter.

It is submitted therefore that one of the principal new factors in the design of European commercial transport aircraft of the near future will be the need for a working height of 10,000 feet, and the problem—to keep to a minimum, both the increase in petrol consumption and the reduction in paying load. Subsidiary problems will be the provision of heating with adequate ventilation.

On the question of seaplane services, beyond pointing out that there are many parts of the world, to mention only two—Calcutta to Australia and the whole of the Mediterranean—where the use of seaplanes is the only reasonable solution, and that these do not fall within the category of specialised transport services, I wish only to draw attention to the connection between night flying and seaplane services.

It requires very little demonstration to show that night flying is more easy to develop over the sea than over the land. The absence of invisible obstructions over the greater part of the route alone is a big factor. This, always assuming the reliable power plant which is promised us, will become less important when the fog problem has been solved, because then night flying land machines will, equally with seaplanes, be enabled to fly high and clear of obstructions en route. Even then, however, the advantage will lie with seaplanes, because of the more expansive landing areas which will always be available for them. In the mean-

time, the first advantage holds good. A moment's consideration of the effect of low clouds at night on a land flying aeroplane which is forced to keep beneath them, convinces one that a regular night flying service by aeroplanes in this climate is at present impossible.

The stricture does not apply with equal force to a seaplane night service. Radiogoniometry, with suitable siting of D.F. stations, is adequate now to bring a machine to an open expanse of water in the vicinity of its destination, where it may be landed without fear of collision with surface obstructions. Instruments for the indication of height above the surface of the water are well forward. Control of the machine in fog is attained. Given all these, a start might well be made, with some hope of ultimately attaining regularity.

The organisation of a seaplane night flying route would cost a fraction of that for a similar land route. It is not necessary to establish a chain of lights in close proximity, even for a land route, but it is necessary to light all the landing grounds and all the key points. For successful navigation, it is not necessary to have a continuous view of beacon lights any more than it is necessary to have a continuous view of the ground by day. The existing marine lights are adequate for the operation of a night flying seaplane service in this part of the world.

Major Mayo's stricture on the seaplane as unseaworthy loses half its force, when it is admitted that the power plant must be made reliable. In any case, the seaplane forced to land in a heavy sea at night is probably no worse off than an aeroplane in similar circumstances forced to land in unsuitable country.

The problem of flying, for example, to Berlin by night becomes easier and cheaper if a seaplane route is followed from the Thames via Kiel and over the Baltic, even if the final stage from one of the Baltic ports, such as Stettin, had to be completed by train.

Major G. P. Bulman: I had not intended to take part in this discussion, but there is a point affecting the engine qua engine in Major Mayo's most interesting and able paper concerning his rather remarkable statement in regard to gearing; the only possible objection which he seems to attribute to gearing is that of extra noise. One can only assume that Major Mayo has had a comparatively quiet life having to deal only with aeroplanes, and that it has not been in his experience constantly to be either designing, manufacturing, maintaining or passing out engines. If he had, I am sure he would regard the gearing of an engine as a confounded nuisance. During the years which have elapsed since the geared engine was more or less standard, engine technique generally has made great advance, and the engineer, therefore, should be in a position more readily to produce sound geared engines. None the less, in returning to gearing, the engine itself is undoubtedly going to be handicapped, increased in weight, afflicted with vibration and developed, as I have said, into a general nuisance. However, since it now appears to be beyond question that from the aircraft efficiency point of view low airscrew speeds are essential, and gearing, therefore, a necessity, it is for the engine people to set about producing satisfactory geared types despite the initial trouble that will have to be faced to get them.

(*Communicated*): The general abandonment of geared engines which took place during the latter part of the War was not, it is thought, so much due to a change in view regarding the relative efficiency of high and low speed airscrews as to the very definite trouble which attended the manufacture, and actual reliability in service, of the geared types, with only one or two notable exceptions. It will be within the memory of those technically concerned with aviation during the War that at least one design originally introduced as a geared type was practically a failure in service and manufactured only with the greatest difficulties, and yet became one of the most successful and valuable designs of the

War when the gearing was deleted and direct drive introduced. It is not unlikely, too, that at least one other type intended for bulk production in the War would have achieved at least some measure of success had its gearing been deleted. To-day there are not wanting many examples to show the remarkable difference in smoothness of running and general "engine" performance between geared and ungeared variations of the same model. One seeks simply to emphasise that the introduction of gears is certainly fraught with difficulty and will require undoubtedly some sacrifice of smooth running and it may be of a measure of reliability (prolonged bench tests give weight to this view). Since, however, predominant aircraft practice so plainly calls for the geared engine one could not contend that the geared type should not be sought for and obtained. The whole history of the "geared versus ungeared" controversy, active or latent for ten or eleven years, is surely a striking example of the need for a combined outlook by both the aircraft and engine designer, to ensure that fundamental requirements are really hammered out and established, that the peculiar needs or difficulties of the one are realised by the other and that together, in agreeing as to what is wanted in the complete machine, they assess and allow for the price (not merely in hard cash) which they must expect to pay to secure their various requirements.

All through the story an independent observer might well have pictured the aircraft designer designing and building his aircraft structure round a mere figure of nett thrust h.p. and total weight to represent the engine, and on the other hand the engine designer seeking only to design the most efficient internal combustion engine for lowest weight, both justifiably gratified with the technical progress they were making. As to whether, however, the engine, when designed, would be of real optimum value in the aircraft, or whether the aircraft structure would be fit to take any real engine whatever, so often seems hardly to have been a matter of definite thought at all. To-day there does seem to be a new spirit of real co-operation and a fusion of thought leading to the evolution of the complete aeroplane as a single piece of design. Had this same unity of attack on the problem, however, been of general standing, and as normal, for instance, as it has been in, say, the analogous shipbuilding industry, such questions as "to gear or not to gear" would surely have been settled fundamentally years ago and our overall progress the more marked.

Captain OLLEY: Speaking about multi-engine machines, I have had some experience, and must say that they imply safety, in spite of the fact that only one of the machines on the European service route will fly when one engine has cut out. It gives you the ability to fly further to safety.

Major Mayo speaks about the rate of fall of aircraft when one engine should fail. He gives specific instances, but I cannot quite agree with that rate of fall. Owing to atmospheric conditions the fall might be either very much less or very much more.

Captain F. T. HILL: I was going to raise one of the points which Mr. Bramson has mentioned, that of the necessity for pilots to know at what angle of incidence they are flying. There ought to be some form of instrument that would give them this important information if flights, under varying conditions, are to be carried out with maximum economy. That such a device has not been developed previously is understandable, as the requirements of a war machine are different, and the question of economical flight must always be secondary to that of carrying out military duties efficiently. It is submitted that on machines designed entirely for civil transport, and of such a size that extra persons are carried for duties which have hitherto been the pilot's responsibility, an incidence meter could be used with considerable advantage.

Captain SAYERS: Major Mayo's paper is one of several on the same subject and one of the few types of lectures which make me regret that I no longer

have actually to design aeroplanes. The problems which the aeroplane designers are asked to solve grow more and more acute every day. We shall have to carry our pilots in suspended bombs to get the view they require, and passengers in a similar method to get them away from the noise of the many engines which are to be used.

The business of the aeroplane designer is to do for one dollar what any other man can do for two. No one can do anything for no dollar. Often the most economical method is to spend 75 cents quickly, while the other man is saving halfpennies. That is the trouble with the aircraft designer. He cannot raise the initial cost of putting a really satisfactory commercial machine on the market. He cannot make a lot of aeroplanes because no one will buy them. He has to make those he can count on selling.

On the subject of multi engines, I am sure that this is a wrong solution of the difficulty. The safest machine is one which can fly with the smallest number of engines. The ideal machine is one that can fly with no engine at all and after that comes the twin which can fly on one.

There is another point on which I cannot agree with Major Mayo, and that is with regard to his estimation on the probabilities of safety with multi-engine machines.

He suggests that the probability of failure of more than two engines on the same flight is remote. It is actually less remote than the probability that the engines of two machines of a number all engaged on the same flight will fail during that flight. And that probability is scarcely remote if the number of machines engaged is fairly large.

The twin that can fly reasonably on one engine is the nearest approach to the ideal of safety that is ever likely to be reached in practice and will pretty certainly displace the triple type in the future.

Major HEMMING: I should like to add my appreciation of this most excellent paper.

From the point of view of air survey I can see that the provision of variable pitch propellers and geared-down engines is going to enable us to reduce our costs enormously, because we shall be able to operate at 20,000 ft. or more, instead of 12,000 ft., nearly doubling the area covered by each photograph. I hope, therefore, that research in this direction will proceed. I should have thought that our requirements of high ceiling, reliability, an unrestricted view ahead and to either side, stability, but sensitiveness to controls, were the same as for high altitude fighting and bombing in the Royal Air Force. Surely, therefore, the Air Council would be justified in assisting by providing the necessary funds for research.

Squadron Leader R. A. DE H. HAIG: Major Mayo states that he thought when we get larger machines we should need some form of servo motor. It seems to me that this is adding a great complication to the machine, and I think the work could be done much more simply by developing our present knowledge of balancing. In other words, using a form of servo control which obtains its power from the airflow past the control surfaces. Any other form of servo motor would only lead to great complication, not to say dangerous, in view of the possible failure of the servo motor.

Mr. W. P. SAVAGE: In this discussion I range myself on the side of Major Mayo on the question of gears and variable pitch propellers. In my opinion it is necessary, in spite of gears being a nuisance, and in this I agree with Major Bulman, to discontinue the use of high "revving" propellers of present design, in the interests of both efficiency and comfort of passengers and crew, and I think we must return to the use of the geared engine with an improved gear, and possibly, a bigger gear reduction than is common to-day.

I was disappointed not to hear some remarks from Major Mayo on operational costs and some suggestions as to how present day costs can be reduced. After all, we have only one end in view and that is to make civil aviation pay its way. It seems to me that the most difficult part of civil aviation is to sell it.

In order to make flying more popular and more economical we have to sell more seats and get more people in the air, and I think we shall only do this by paying more attention to the mental and bodily comfort of the passenger who, after all, pays a high price for his travel. While safety is the first essential, I submit that comfort is almost equally important. The speed of 100 miles per hour has come to be looked upon as the economical speed of commercial aircraft without, I submit, any commercial results to support it, and it seems to me that we could reduce that so-called economic speed by 10 per cent. and use the engine power thus released in carrying the added weight created by providing the passenger with a more comfortable journey.

Major Mayo draws comparisons between the air-cooled and water-cooled engine in considering maintenance. I think it is only fair to bear in mind that the figures given in respect of the water-cooled engine are applicable to engines of old design and I doubt whether they would apply to the modern engine.

There has been a little discussion as to the date when a certain well-known aeroplane started life on the London-Paris line. It was in May, 1922. I am very pleased to hear that those three old machines are still giving good service, and in this connection there is one small point I wish to make and that is, that Major Mayo, instead of generalising on the question of the flying life of these machines by using the phrase "thousands of hours" might have been a little more impressive by saying "approaching four thousand hours each."

In his list of suggested developments I was disappointed that Major Mayo did not include a "pusher" machine. I have thought for a number of years that the "pusher" machine should be developed for passenger work, as with this type a good deal of the noise is left behind, particularly propeller noise, which is the most difficult to eliminate.

Captain NICOLSON: I think that apart from the scientific reasons for fitting three engines in an aeroplane, the fact of having multi-engines will give confidence to the man in the street. I have seen this same reasoning apply to the number of funnels on a ship. One particular case I know of where several hundred emigrants would not sail when the shipping company landed them alongside a vessel with only one funnel. Most of these people had to be housed for a week until a vessel with two funnels arrived. These people had booked to a plan showing a ship having multi-funnels and actually declared that they thought they were safer.

We naval architects often design ships with multi-funnels as we know they prove much more popular. Only a few years ago I designed a vessel with three funnels, two of which were dummies, and this ship proved to be the one most patronised by the public.

To come back to the aeroplane engine, I do not agree with many of the previous speakers that we must revert to geared engines, although I realise we have recently had trouble with direct drive propellers, as the tip speed was as great as the velocity of sound, and at tip speeds of 400 ft. per second, we are apt to get flutter, and at the moment we do not seem to know exactly how to cure this. However, I maintain that it is the propeller that is at fault.

When I was a student of naval architecture we were instructed never to run a marine propeller at speeds over 200 revs. per minute, but to-day we have modern engines and propellers turning at over 6,000 revs. per minute and giving a very good efficiency. I submit that if marine experience shows that efficient direct drive high speed propellers can be made, that aircraft propeller designers should look to it that they do the same.

I was glad to hear Mr. Handley Page speak on the side of marine aircraft. However reliable the aeroplane becomes, there will always be room for the seaplane. This is natural as three-quarters of the earth's surface is covered with water and therefore more scope for operating seaplanes.

Again, as aircraft become larger, the flying boat gets safer and can land at higher speeds than aeroplanes with safety.

If you try to land an aeroplane, weighing say 30 tons, on a wet and soft aerodrome, it would probably dig its wheels into the ground and turn turtle, while a flying boat of the same dimensions would form a cushion of air between the bottom of the hull and the surface of the water and make a nice and soft landing. To this the lecturer might say that when large aeroplanes are used a special concrete aerodrome would be laid, but as this would be very expensive, the flying boat would prove to be the better commercial proposition.

The pilot of a flying boat has always a seadrome under him and this is specially useful for night flying.

If an aeroplane is operating in foreign countries, great expense is entailed in the upkeep of aerodromes, while the flying boat has already made rivers, creeks, or harbours, and as nearly every large town is situated on a river, it is my opinion that the commercial machine of the future will be the large flying boat.

Mr. J. L. PARKER: I do not quite agree with Major Mayo that the great reliability to be expected with multi-engined land machines will detract from the usefulness of the seaplane for, I think, it is quite probable that the performance of the seaplane will be superior to the land machine, particularly in large sizes when designed to operate normally from smooth waters.

I may be more sensitive with regard to noise than many people and I think this is a very important point indeed and agree with Major Mayo that the additional noise by the use of gearing would be more than offset by the reduction in that of the propellers by reason of their slower speed. I thank Major Mayo for his very valuable paper.

Mr. BOULTBEE: The variable pitch propeller is certain to be very considerably heavier than is the ordinary propeller, and it will be very liable to get out of order. The problems in the control of it in multi-engine aircraft seem to me to be very serious, and on the whole I should think it would be some considerable time before they are used in service.

Mr. F. RADCLIFFE: In the course of his paper Major Mayo has mentioned the flight by the first "Hercules" to India and back as though it were a very wonderful feat. In the same category, Cobham's flight to Australia and back and those done by many other machines that have flown greater distances would be placed.

As a member of the younger group of aircraft designers, who has faith in future commercial flying, it does not strike me as being so wonderful after all. Surely all of us who believe in air transport must realise that the possibility of getting safely to one's destination must be made very certain if we wish the Aerial Age to come into being, and it is only when that element of risk can be reduced to an absolute minimum that we can speak of commercial aviation. Thus, so long as the completion of a long distance flight remains a wonderful feat, so long will commercial aviation not be an actual fact.

Public confidence in flying, created by commonplace regularity alone, will do much to hasten the time.

If I wish to go to Paris and back and I go by air, there is a possibility of a forced landing, and it would seem that, after all, the quickest way is by boat and train. This chance of a forced landing is not the only deterrent. Major Savage has mentioned comfort, and here is a factor which needs *very* much greater attention than it has otherwise received.

I recently had experience of flying in both the "Hampstead" and the "Argosy," and would say definitely that neither can offer the comfort one gets in an old Ford. As for noise, I made every possible use of the cotton wool so thoughtfully provided, but that did little good. The side bracing wires come through the woodwork on the latter machine, and all round the wire is a good big clearance for all the draughts to come through. Furthermore, there is an engine attached to the nose of the machine and one on either side of the body. The one on the nose makes you aware of its presence by the vibrations it transmits to the passenger cabin, and especially if there should be any irregularity in the firing of its cylinders. In my opinion the engines should not be attached to the body, but placed on the wings. The noise is far too great with them placed as they are, and it would appear that a better position for them would be nearer the trailing edges of the wings, because then the noise would be behind the passengers. "Ripping" panels when placed on the top of the cabin ought to be waterproof, so that when there is rain they do not become "dripping" panels to the discomfort of the passengers.

Then there is the design of chairs. From the "Hampstead" one gets out with cramped knees, and from the "Argosy" with a stiff neck, due to not being able to sit back with one's head against the back of the chair. I think a little more comfort is desirable here.

The cantilever monoplane wing seems to me an absolute necessity for passenger machines. With the present wide wings of the biplane, all that some of the passengers can see is an expanse of fabric, which is a dull sight. If we place a monoplane wing above the cabin, the passengers have a clear view, and we make flying a little more interesting to them, for after all, with the novelties of flying gone, it can certainly be said that flying in a commercial air-liner is dull.

Mr. Bramson has raised a point with regard to the control of variable pitch propellers. I think the Chairman will not object to my mentioning the fact that the Gloster Aircraft Co. are going ahead with a form of variable pitch propeller that can be operated mechanically or by the pilot. This unit, which is a development of Dr. Hele Shaw's invention, and for which my firm hold the world patent rights, is giving very satisfactory results in the experimental stage, but more of this can be told later when it is ready for public use.

I would like to endorse the statement made by Major Mayo concerning detail design. My impression is that we do not pay sufficient regard to the detail working parts of aeroplanes. Fortunately, the Airworthiness Department of the Air Ministry have this matter in hand, and it is with a view to making controls more efficient and longer lived that experiments are being carried out at the R.A.E. The result of these should be a great improvement in this realm of design.

Each firm seems at present to have its own ideas as to the standards required in detail design and their variation is as wide as can be imagined.

Surely there must be some one standard which is right, and if this were established as right it would both make it easier for design departments throughout the country and for the Airworthiness Department.

The CHAIRMAN: Before asking Major Mayo to reply, I should like to make a few remarks.

Reference has been made to the ill-effects on the public mind brought about as the result of accidents, and it would seem quite definite that this unfortunate state of affairs could be largely put right if the findings of the Accidents Investigation Committee were made public. The keeping of them secret can serve no useful purpose, but it engenders a spirit of mystery and mistrust.

Night flying is most essential, without it we shall not get very far, and it is to be hoped that Major Mayo, as Technical Adviser to Imperial Airways, can induce that organisation to embark on a generous programme of night flying development.

Variable pitch propellers are, as has been rightly pointed out, essential. Spasmodic attempts have been made during the past 12 years to produce a satisfactory gear. Although the advantages have gradually been recognised by an increasing number of people, very little has been done until quite recently.

The previous speaker has alluded to the hydraulic variable pitch gear; in my opinion this will be the gear of the future, in fact to-day it is recognised as holding the field against all mechanical competitors. I would like to ask Major Mayo his opinion on this.

The Lecturer is quite right in saying that you must have geared engines. If their adoption increases the noise problem, then steps must be taken to insulate the passenger cabin more effectively.

Personally, the only point of disagreement I have with this admirable paper is in its reference to seaplanes. The Lecturer, I think, very seriously underestimates the great possibilities, not necessarily of the immediate future, but of the present, that the flying boat offers. If heavier-than-air craft are going to be used for commercial purposes, a very large portion of the world's traffic will be carried by flying boats. They offer a number of great advantages over aeroplanes. Take for example one question alone, that of night flying, or flying in bad visibility. We have heard that the Lecturer has changed his views quite considerably since the first Air Conference, and I hope that on this question he will have changed his views when we have the pleasure of listening to another paper from him.

The question of relay controls is important, and for the very large machines some means of taking the work off the pilot will have to be found.

With regard to slotted wings, it does seem strange that the Handley Page "Hamlet," ordered by the Department of Civil Aviation to test out this device on a commercial type, should have been lying idle for so long without any engines. In view of the very successful results that have been obtained in other directions, this apathy is all the more surprising.

Replies to Discussion

Mr. F. Handley Page.

Mr. Savage came to my rescue in regard to the date when a certain machine was built so there is no need for me to defend myself against Mr. Handley Page's reproach.

I am very glad that Mr. Handley Page agrees with me as to the importance of discriminating between the risks in military flying and air transport. I do not think there is any doubt that the popularisation of air transport has been very seriously retarded through prejudice arising from the very large number of accidents which has occurred in other branches of flying.

With regard to the question of night flying I certainly agree with Mr. Handley Page that this problem will have to be tackled seriously sooner or later. Personally I think it is of greater importance in the case of the North West European services to concentrate attention on day flying until a standard of safety and reliability commanding the complete confidence of the travelling public has been achieved. It must be remembered that in North West Europe the difficulties arising from unfavourable weather conditions are very great and although enormous strides have been made in the direction of overcoming these difficulties there is still a good deal to be done before night flying can be tackled with the same degree of safety as day flying. As my paper was intended to deal mainly with questions relating to design, I did not attempt to go into the meteorological problems involved. So far as design is concerned it seems to me that the main principles to which I have referred in my paper hold good to an even greater extent for night flying than for day flying. The case for the multi-engine machine where night flying is concerned is unanswerable. It is also evident that improved aerodynamic qualities will be of very great value in night flying. I do not myself

think that the time has yet arrived for night flying to be undertaken except in countries where the climatic and geographical conditions are particularly favourable.

With regard to Mr. Handley Page's remarks on the subject of marine aircraft, I think that he and several other speakers somewhat distorted what I said. I fully agree with Mr. Handley Page that there will be a number of purposes for which marine types of aircraft will be specially suitable. It appears to me, however, that for long distance transport work land type aircraft will have certain advantages in regard to the amount of paying load which can be carried, and if a standard of almost absolute reliability is attained, I do not see why land type aircraft should not be preferred for this class of work.

Mr. Handley Page has always been an apostle of the twin-engine machine and I am not surprised that he looks forward to the reversion to the twin-engine machine which variable pitch propellers and geared down engines would make possible. It cannot be denied, however, that the multi-engine machine will give a greater measure of reliability than the twin-engine machine even when the latter is capable of maintaining flight on one engine. I do not think there is a great deal in the argument that the multi-engine machine involves complications and weight in the piping and engine mountings. The same argument can be applied to the twin-engine machine as opposed to the single engine machine. The multiplication of engines does undoubtedly cause a certain increase in the complication of engine controls, etc., but this disadvantage is of very minor importance compared with the great advantages gained.

In reply to Mr. Handley Page's remarks on the subject of the slot and aileron control and its application to commercial aircraft, I would point out that the great difficulty from the point of view of the operating companies is that there has been no clear evidence available as to whether the use of such controls is justifiable or not. I would remind Mr. Handley Page that none of the machines operated by the air transport company which bore his name, was ever fitted with slotted wings although that company was functioning several years after he had produced the invention. The great difficulty which operating companies experience in regard to such developments is lack of funds to pay for the cost of the necessary experimental work involved. They cannot afford to risk money on anything that is not an absolutely proved success.

Mr. Bramson.

I think that a variable pitch propeller should be operated automatically, but that the pilot should be provided with an over-riding control enabling him to set the pitch at any setting required for various conditions of flying.

With regard to Mr. Bramson's remarks about angle of incidence, I agree an angle of incidence indicator is a useful instrument, but it does not appear to me to be an essential instrument for commercial aircraft. Although the optimum flying speed may vary according to the load carried the amount of variation is comparatively small. Moreover, slight variations from the optimum speed have very little effect on the rate of climb or ability to fly in the case of one engine failure. If and when variable pitch propellers become available, it will be much more worth the pilot's while to fly accurately at the optimum speed in the case of engine failure.

I do not think it is necessary to reply seriously to Mr. Bramson's suggestion that Imperial Airways is taking money on false pretences. It would be equally reasonable to say that the L.G.O.C. are taking money under false pretences because the man in the street who takes a penny bus ticket is under the impression that the buses run with complete immunity from skidding. The L.G.O.C. has directed its attention for many years towards the elimination of skidding in its latest design of bus, but it cannot be expected to scrap its entire fleet every time an improvement in design is effected. Imperial Airways have directed their policy towards the

attainment of reliability by the use of multi-engine machines, and if aircraft designers have not yet been able to produce the perfect article, Imperial Airways cannot be blamed for that.

Colonel Barrett Lennard.

I am in complete agreement with Colonel Barrett Lennard's remarks in regard to the importance of the question of cost. There is no doubt that there is room for a considerable reduction on the capital outlay and operating costs involved. I had hoped to include a section on this subject in my paper, but as I explained I was forced to omit it owing to the length of the paper and the time I had available. My main argument was directed to emphasising the importance of safety and reliability and I expressed the view that as these features in air transport are developed the confidence of the travelling public will be more firmly established and the prospects of operating companies will be correspondingly improved. As the volume of business increases the number of aircraft employed will also increase, so that there is a prospect of achieving some reduction in the capital cost of aircraft in this way. At the same time I entirely agree with Colonel Barrett Lennard that designers should give much more attention to this very important aspect of aircraft and engine design.

I also agree with Colonel Barrett Lennard that British designers have been too conservative and there has not been sufficient research and experiment with new types of construction. Unfortunately the amount of support which the Air Ministry can give in this direction is strictly limited owing to the smallness of the vote for civil aviation in comparison with that for military aviation. There is no doubt that the progress made in the design of commercial aircraft by German firms has been largely due to the fact that Germany has not been saddled with the cost of maintaining an Air Force.

Mr. C. C. Walker.

With regard to Mr. Walker's contention that the multi-engine machine presents such formidable difficulties, particularly in regard to the placing of the engines, I do not believe these difficulties will be found to be nearly so great when they come to be seriously tackled. I quite agree that a twin-engine machine which can fly with a good load on one engine will have great advantages as a commercial type, but it seems to me that it will be very difficult to produce such a machine. I endeavoured to show in my paper that with the use of geared engines and variable pitch propellers it would be possible to design a twin-engine machine to carry an effective load and maintain its height in case of one engine failure. In the case of such a machine, however, the one remaining engine would have to be run at full throttle, or very nearly full throttle, and under these conditions the risk of breakdown would be appreciable. In the case of the multi-engine machine failure of one or even two engines will not necessitate running the remaining engines at full throtle and it is for this reason that the multi-engine machine can be made so much more reliable than the twin-engine machine.

Mr. Walker quite rightly points out that an engine placed in the nose of a body of large section is not very efficient. I agree that this is a strong argument against the disposition of engines in the present day three-engine type of aircraft, but I do not agree that it is a substantial argument against the multi-engine machine. The arrangement of engines in tandem has by no means been fully explored and there are other possible arrangements of engines which would get over Mr. Walker's objection.

Mr. Walker's disclosure in regard to crop protection and pest destruction was dealt with by Captain Tymms. It seems incredible that so valuable a means of assisting agriculture could be regarded as illegal.

Captain F. Tymms.

I am in complete agreement with Captain Tymms as to the vital importance of overcoming the difficulty of bad visibility. In a paper on air transport operation

I should have emphasised this point much more strongly, but I purposely avoided it as the paper was intended to deal with the design aspect of commercial aircraft.

I entirely agree with Captain Tymms that when satisfactory means of landing in fog have been evolved, flying will naturally be carried out at a much greater height than is the case at present. Given a reliable aircraft and a reasonable certainty that he will be able to land safely at the end of his journey, there will be nothing to prevent the pilot from climbing up through the fog or clouds and making the journey in comfort and sunshine. It will never be possible, however, to operate air transport on these lines with aircraft which are liable to forced landings and to my mind the success of this method of dealing with conditions of bad visibility is tied up with the use of multi-engine machines. The use of geared engines and variable pitch propellers, which I advocated in my paper on the grounds of reliability and safety, will of course be of vital importance in enabling aircraft to operate at the great heights referred to by Captain Tymms.

Captain Tymms makes a strong case for the seaplane, but he and several other contributors to the discussion, have misinterpreted my remarks on this subject. I quite agree that there are many parts of the world where the seaplane is more suitable than the aeroplane for air transport work and I also agree that even in the future when the reliable aeroplane has been established there will still be many valuable uses for the seaplane. It does seem to me, however, that the development of the absolutely reliable aeroplane will inevitably reduce the scope for the seaplane. Captain Tymms holds that the seaplane will be much more suitable than the aeroplane for night service. The argument does not appear to me to be a very sound one. When the difficulties of night flying have been overcome and the really reliable aircraft has been established it appears to me that it will be just as easy to run night services with aeroplanes as with seaplanes.

I very much doubt whether Captain Tymms's argument in regard to the cost of lighting, ground and sea routes for night flying is sound. It is the geographical conditions between any two given places which must determine the nature of the lighting arrangements on the route. While it is true that many large cities are situated near a river or near a large stretch of water, it is also true that all cities are built on land. It seems to me that the logical solution is to use land type aircraft and to make them immune from forced landing between the terminal points on the journey whether they have to travel over land or water.

Major G. P. Bulman.

I am very glad indeed that Major Bulman has given his support to the argument that geared down engines must be produced, because they are so urgently required by aircraft designers and operators. Major Bulman has pointed out the difficulties involved in the use of reduction gears and it is evident that some sacrifice must be made in the use of such gears. I referred in my paper to the disadvantage of noise in particular, but there is also, of course, the question of weight which has to be considered. There can be no doubt, however, that the advantage gained from the use of gears, far more than compensates for the extra weight involved.

Major Bulman quoted some examples of war time engines which did very much better ungeared than geared, but I would suggest that now that engine designers and those responsible for engine development generally are not so pressed for time as they were during the War, it will be possible to produce very much more reliable reduction gears than was the case during the War.

I certainly agree with Major Bulman as to the advantages to be gained by closer co-operation between aircraft and engine designers.

Captain Olley.

I am very glad that Captain Olley gave us the benefit of his brief remarks in support of the multi-engine machine, as he has had wide experience on both single and multi-engine machines.

I quite agree with him that the rate of loss of height in the case of one engine failure will vary according to the atmospheric conditions. In the example I took in my paper, I assumed calm conditions, as otherwise it would not have been possible to arrive at any definite result. As a matter of fact, bad atmospheric conditions are likely to have a marked effect on the ability of an aircraft to fly at considerably reduced power and it will therefore always be difficult to design a twin-engine machine which will maintain height under unfavourable conditions with one engine completely out of action.

Captain F. T. Hill.

Captain Hill supported Mr. Bramson in emphasising the importance of the incidence meter. I have already dealt with this point in reply to Mr. Bramson.

Captain Sayers.

I quite agree with Captain Sayers' argument that aircraft designers are hampered by the lack of orders for new types of aircraft. My own view is that a very much larger proportion of the total Air Ministry vote ought to be devoted to the development of commercial aircraft design than is the case at present.

I quite agree with Captain Sayers that the ideal aircraft would be the single-engine aircraft, provided the single engine could be made absolutely reliable. I do not think, however, it is reasonable to suppose that anything approaching absolute reliability in aircraft engines can be expected for many years to come, and this being so it seems to me the balance of argument is very strongly in favour of the multi-engine machine.

In the case of a machine fitted with a considerable number of engines, say, five or six, I cannot agree with Captain Sayers that there is an appreciable risk of having more than two engine failures during a single flight. Statistics for British air transport operations show that an engine failure necessitating a forced landing is a very rare occurrence. The risk of two engines failing on the same flight is exceedingly small and the risk of more than two engines failing is almost negligible. It should be remembered that in the case of the multi-engine machine failure of one or even two engines will not necessitate running the other engines at full power and this makes a vast difference to the risk of further failure. In the case of the twin-engine machine the remaining engine must be run at full power or approximately full power, and under these conditions it is much more liable to failure than under normal conditions. It is, of course, possible to design a twin-engine machine which will fly comfortably on one engine, but it is not possible to design such a machine to carry sufficient paying load to be commercially profitable.

Major Hemming.

I am very glad Major Hemming pointed out the value of variable pitch propellers and geared down engines in the case of aircraft for air survey work. All the arguments which I used in the case of air transport apply equally well in the case of the air survey machine, and in addition there is the great improvement in rate of climb and service ceiling which they would effect.

I agree with Major Hemming that variable pitch propellers and geared down engines will be equally valuable in the case of military aircraft.

Squadron Leader R. A. de H. Haig.

I quite agree with Squadron Leader Haig that the use of servo controls is undesirable if the controls can be sufficiently well balanced aerodynamically. It appears to be possible to balance the controls satisfactorily for aircraft up to the sizes at present in use, but I do think it will be necessary to provide servo controls if the size of aircraft increases appreciably in the future. I do not think the provision of a servo motor to assist the pilot in controlling the aircraft need necessarily lead to great complication and there would be no added danger

in case of failure of the servo motor, because the controls would in any case be balanced as well as possible.

Mr. W. P. Savage.

I am very glad that Mr. Savage supports the idea of using reduction gears and variable pitch propellers.

I fully agree with him that comfort of passengers is a most important matter and that it should be given the most careful attention of designers and operators. I am very doubtful, however, whether a reduction in cruising speed of 10 per cent., and the use of the engine power thus released in carrying additional weight created by providing greater comfort, would be feasible. The effect of this on the cost of operating would be very serious. My own personal view is that the discomfort of air travel has been very greatly exaggerated. To my mind, far the greatest source of discomfort is noise and I do not think it will be impossible to overcome this trouble without adding substantial weight to the structure of the machine.

With regard to Mr. Savage's remarks about the development of a " pusher " type machine, I did not refer to this specifically in my paper, because I am not at all clear myself that the " pusher " type offers very great possibilities. There has been a good deal of discussion on this subject recently, but I do not know of any very concrete proposals for the design of a " pusher " type passenger aircraft. It is obvious that considerable difficulties are involved in designing a " pusher " type machine, particularly in regard to the position of the C.G. in relation to the wings. It may be possible to overcome these difficulties satisfactorily, but I do not think it is to be expected that any appreciable advantage in regard to noise will be gained unless the passenger cabin is placed well forward of the engines. Merely moving the engines from positions level with the forward end of the cabin to positions level with the aft end will not solve the problem of noise.

Captain Nicolson.

The analogy of the multi-funnel ship is interesting, but I would suggest that the size of ship may have something to do with this question of public performance. I think it is generally true that large ships have two or more funnels, while smaller ships very often have only one. I feel sure that the travelling public has a marked preference for large ships and this preference is no doubt based on sound judgment. A similar preference for the larger types of aircraft is undoubtedly developing and I think this preference is also based on sound judgment. The large multi-engine machine undoubtedly gives a feeling of confidence to the passengers. But the travelling public are more discerning in their appreciation of the value of three engines in an aircraft than in the case of the three funnels of a ship; they appreciate that the three-engine machine is in fact safer and more reliable than the single-engine machine.

I cannot altogether agree with Captain Nicolson's remarks in regard to propeller design. The aircraft propeller problem is essentially different from the marine propeller problem. The designer of the marine propeller is not faced with the problem of obtaining high efficiency at high revolutions and full power throughout a wide range of forward speeds.

With regard to Captain Nicolson's argument that a large aeroplane will be liable to dig its wheels into the ground and turn turtle, I do not think there is a great deal in this argument, because as the size of the aeroplane increases so also does the size and bearing area of the wheels increase. It is not by any means necessary to have a concrete aerodrome for large sized aeroplanes. On the contrary, as the size of the aeroplane increases a considerably rougher surface can be used, as small irregularities and obstructions become of less importance.

Mr. J. L. Parker.

Mr. Parker suggests that the performance of the seaplane of the future will be superior to that of the land machine. If this is so I quite agree that the argument in favour of the use of land type aircraft for long distance transport work is to a great extent destroyed. Up to the present time, however, I think it is true to say that it has not been possible to design marine aircraft with the same carrying capacity and performance as land aircraft, and my argument was based on the assumption that this would continue to be the case in the future. It must be remembered that the seaplane must not only improve in efficiency, but it must also improve very considerably in seaworthiness before its advantages over the aeroplane can be realised in practice.

Mr. Boultbee.

It is, of course, true that the variable pitch propeller will be considerably heavier than the ordinary propeller, but the increase in weight will not be comparable with the additional paying load which it will be possible to carry with the same degree of safety.

As regards the liability of the variable pitch propeller to get out of order, this argument is invariably applied to any new mechanism. I do not see why it should be impossible to produce a variable pitch propeller of high reliability, and I believe that such a propeller will be produced before very long.

I do not agree that the problem of controlling variable pitch propellers in multi-engine aircraft is very serious. The same argument was applied in regard to the control of the engines in the early days of three-engine aircraft, but I think any experienced pilot of multi-engine machines will agree that there is not much in this argument.

Mr. F. Radcliffe.

Mr. Radcliffe has misinterpreted my remarks in regard to the flight of the Secretary of State for Air to India and back. I did not quote this as in any way "a wonderful feat." I merely quoted it as an example of the progress made in the design of commercial aircraft, the main point being the confidence displayed by the Secretary of State and by the British Government in allowing a Cabinet minister to make the journey.

I agree with Mr. Radcliffe that air travel must become commonplace before air transport can pay its way, but I would suggest that it is up to the younger group of aircraft designers to produce the goods which will make air travel commonplace.

As I have said in reply to other speakers, I quite agree that the question of comfort is a most important one, and again I would suggest that the younger group of aircraft designers should show the way to the solution of the problems involved. As I have said before, I think myself that the discomfort of air travel has been greatly exaggerated. I had the pleasure of being a fellow-passenger with Mr. Radcliffe on his journey to Paris in the Hampstead machine. Personally I thoroughly enjoyed the journey, and I think it is possible that as Mr. Radcliffe acquires more experience of air travel he will think less of the discomforts and more of the great advantages over other means of travel.

I entirely agree with Mr. Radcliffe that the cantilever monoplane type offers very great possibilities, particularly in regard to view for the passengers. I have never been able to understand why the Air Ministry did not proceed with the programme of experimental design which was started several years ago in this country. One type of cantilever monoplane passenger-carrying machine was designed and built in this country, but the experiment was abandoned before any reliable information was derived from it. The trouble is that insufficient funds are allocated for the development of experimental designs of commercial aircraft.

Colonel the Master of Sempill.

I am very glad that our Chairman has referred to the secrecy maintained in regard to the work of the Accidents Investigation Department. I am convinced myself that the value of the Accidents Investigation Department would be considerably enhanced by the adoption of a courageous policy in regard to the publication of reports. I suppose there are two main arguments against the publication of such reports :—

(1) That information of a secret nature might be disclosed, and

(2) That the findings must sometimes involve criticism of pilots or others based on opinion rather than proved fact.

To my mind both of these arguments are fallacious.

In regard to the first the information disclosed would be of no value to any possible enemy and its effect on public opinion in this country would certainly be better than that of the rumours which float around as to the causes of Service accidents.

In regard to the second argument, it is conceivable that injustice would sometimes be done, but the importance of this would be negligible in comparison with the value to pilots in general of publication of the reports.

With regard to the question of night flying, as I have stated in my reply to Mr. Handley Page and others, I do not myself see the object of trying to establish night services between England and the Continent at the present stage of development. To my mind the right policy is to hammer away at the day services until they have been made absolutely safe and reliable under all weather conditions. When it has been made possible to take off and land in fog and navigate a course from the starting-point to the intended destination, then, and then only, can regular night services be undertaken with confidence. At the present time it seems to me very doubtful whether there is any particular advantage to be gained by running night services, but there will undoubtedly be need for such services when air transport has developed further. The introduction of night services will present no difficulty when the problems involved in bad visibility have been satisfactorily overcome.

I agree with the Chairman that the hydraulically operated variable pitch propeller appears to be very promising. The hydraulic principle is undoubtedly one of the simplest and most reliable for mechanisms of this sort. A well-known example of the application of the hydraulic principle is the Constantinesco gun gear for firing through the propeller. This mechanism proved to be far superior in reliability to any of the purely mechanical gears produced.

I agree that the flying boat offers great possibilities at the present time, but my remarks in this connection were directed towards the future when absolute reliability has been achieved. It seems to me that there has always been a good deal more talk about the advantages of seaplanes than practical use of this class of aircraft. I would suggest that the marine type is in fact no more useful for air transport than has been proved to be the case in actual practical service. The vast preponderance of land types in air transport suggests to my mind that land types are in fact generally more suitable for air transport.

The Chairman commented on the fact that the Handley Page "Hamlet" machine which is fitted with slotted wings has been lying idle for some considerable time. When I mentioned that the value of slot and aileron control had not been demonstrated in any full-size commercial machine I did not forget the "Hamlet," which I knew to be tucked away peacefully at Cricklewood. It must be remembered that it is a comparatively small machine and not suitable for general use on the European services, but the information to be derived from it will be extremely interesting if and when it becomes available.

PROCEEDINGS

SIXTH MEETING, SECOND HALF, 62ND SESSION

A meeting of the Royal Aeronautical Society was held in the Theatre of the Royal Society of Arts, 18, John Street, Adelphi, on Thursday, March 10th, 1927, when a paper on " Man and the Machine " was read by Group Captain M. Flack, C.B.E., M.B.

Colonel The Master of Sempill, Chairman of the Society, presided.

MAN AND THE MACHINE

BY GROUP CAPTAIN MARTIN FLACK, C.B.E., M.B., M.A.

What may be termed broadly the medical aspects of flying are far more wide-reaching than is generally supposed, especially since such a term embraces both the physiological and psychological aspects of the subject. All the while, therefore, that man acts as the controlling and co-ordinating mechanism of the machine, the study of man in relation to his machine must occupy an important place in the progress of aviation. It is because this aspect of the subject has tended to be somewhat overlooked that I venture to address this Society again to-night.

In the first place I wish to consider what happens when a man learns to fly. As the result of information gleaned by his various senses he is taught, according to his aptitude, to perform or to try to perform certain arm and leg movements which will control the machine safely while it is in the air. To do this, however, in addition to perceiving, he must in certain circumstances display judgment before he acts, although, as he becomes more experienced in flying, he will automatically perform certain movements in response to certain sensations. For example, in response to a certain " feel " of the control column or seat he will, when experienced, immediately perform a certain movement which he has learnt, or been taught makes for the safety of himself and the machine; a case in point is automatically putting the nose down when the " feel " of the control column indicates that the stalling point is near.

Broadly speaking, it is the degree of automaticity exhibited in flying which differentiates the experienced, skilled pilot from the inexperienced one. In the early stages of flying, the novice relies almost entirely upon visual information conveyed to him either from his external surroundings, the horizon, etc., or from instruments upon his dashboard. During this stage, while every limb movement is the result of conscious effort, he gradually learns to realise the importance of the other sensations of what is popularly known as the " feel " of the machine, the " feel " of the control column, rudder bar and seat. He gradually becomes aware also, through hearing, of the importance and significance of the note of the " singing " of the wires, or of change of note in the engine, also through tactile impressions of the meaning of change of direction of air currents upon the face. Having learnt the importance of these, he acquires gradually, as I have said, a more or less automatic response to the information thereby conveyed, although he may not appreciate that he is doing so. But throughout his flying career it is by visual impressions that the most important messages are conveyed, since it is primarily in response to these messages that judgment must most frequently be exercised, quick decisions made and appropriate movements of the limbs performed, if the machine is to be kept in the air in a position of safety.

It is frequently stated that a man can fly safely without the use of his eyes. This is an absolute fallacy. It is true that a blindfolded passenger can for a time appreciate what is happening to him in a machine, but only for a time; later he becomes distinctly muddled and will believe that a machine is still turning when after a turn it is flying straight, and so forth. After aerobatics he will be even more worried and his opinions as to what is really happening even more erroneous. But the crux of the matter is when it comes to flying blindfolded.

Let anyone who believes that he can fly without the use of his eyes assume control of a dual machine, always, for his own sake, with an experienced pilot ready to take control in emergency. He will be surprised at his lack of ability to fly correctly, although he will by this means also learn how much he relies upon the "feel" of the control column, rudder bar and seat. Yet, as I have said, he will not, without the use of his eyes, be able to fly correctly; he will get off an even keel, tend to stall or nose-dive, and may even get upside down. It is on this account that fog flying and cloud flying present so much difficulty, and without the aid of information through his eyes from instruments, no pilot can fly successfully in fog and cloud when all external information to the eyes is cut off.

On this account the control or turn indicator is such an important instrument to the pilot. Although much has been said of the value of the semi-circular canals of the internal ear in providing information as to a man's position in space, this idea of their functions as regards flying is erroneous. For safety in flight under such conditions the machine must be provided with some mechanism which indicates whether or not it is on an even keel and the information must be conveyed by visual means.

This brings me to an important point. Since visual impressions play so great a part in flying, it is obviously to be aimed at that the visual information, which it is necessary to convey to pilots by instruments for the safe control of the machine, should be placed so far as possible in the same field of vision. In other words, the ideal scheme would be that instruments connected with flying should be in one sector, those connected with engine control in another sector, those with navigation or wireless in another sector, and so forth. Such an arrangement has been advocated from the medical point of view for many years past, and I understand that something is now being done in this direction. It is important, since when quick action is necessary, the difference in time taken by the pilot in gleaning the necessary information from instruments correctly grouped or from instruments scattered haphazard in odd positions may make all the difference between safety and disaster.

Another point to be borne in mind here is the means by which his visual information is to be conveyed. Figures and needle points are only appreciated by direct central vision of the eyes, which is a relatively limited field, from 6-8 degrees. On the other hand, information transmitted by means of lights so set to have a wide luminous range is appreciated by peripheral vision through an area of approximately 180 degrees.

Therefore, the instruments in which definite information can be conveyed by figures should be placed in the central visual field, those where information can be conveyed by lights can be situated somewhat more peripherally.

Another aspect of this question is that where information is of vital importance, conveyance of information by such means of light is of value, since it will be appreciated by a pilot whether he is looking directly at the instrument or not. Moreover, it has to be remembered that the vibration of needle points and the necessity of reading the information of many such needles induces ocular fatigue, as well as raising the problem of correct and adequate illumination at night.

A further point to which I would draw attention is that for the sake of correct visual judgment the pilot should as far as possible be given a standard position in the machine from which to form his external judgments. For example,

in learning to fly he forms many judgments by looking horizontally along the nose of his machine at the horizon and observing their relative positions to each other. Now, since these early impressions always remain, it only adds to the difficulty of satisfactorily manipulating a machine when a pilot on another model finds himself so seated that he either cannot take a horizontal line along the nose of his machine to the horizon, or the nose is so shaped that glancing along it affords another line of direction to that usually given.

This may appear only a small matter to the experienced pilot, but it is of greater importance than is usually realised. Again, machines should always be designed so as to afford the pilot the widest possible range of vision—any large objects placed relatively near the eye tend to distract attention and to prevent or impede binocular judgment.

Before leaving this question of adequate visual perception I would draw attention to the importance of good binocular vision for efficient flying, especially for satisfactory landing of the machine. As is well known, many pupils experience great difficulty in landing satisfactorily; in fact, some can never do so, and in consequence the question of discontinuance of training arises. Wing Commander Clements, of the Royal Air Force, was the first to show that in many cases this disability is associated with defective visual judgment owing to the two eyes not acting in concert, and he has shown that, by inducing in such subjects correct binocular judgment by means of special eye exercises, such bad landing propensities can be overcome in many subjects, turning them into successful pilots.

I would point out, however, that all bad landings are not necessarily due to bad perception; some may be due to bad performance, and it is necessary to distinguish carefully between the man with good perception and bad performance, and the man with bad perception and potentially good performance.

This brings me to my next point, namely, that all men are not endowed with the ability of making the necessary co-ordinated movements of arm and leg necessary adequately to control a machine. As is well known, some men have poor co-ordination of the muscles of the upper limb and cannot adequately work the control column, and are termed heavy-handed; others are heavy-footed and cannot work the rudder satisfactorily; others, while being able satisfactorily to manipulate the control column alone or the rudder alone, cannot work the upper and lower limbs together in co-ordinate fashion and are thus unable to perform satisfactorily the combined movements of flying.

It is obvious, therefore, that if such people could be detected at an early stage of flying instruction or before such instruction began, much instructors' time would be saved and much damage to machines and possibly to the individuals themselves avoided.

Accordingly, during the past ten years considerable study has been made in various countries of what are known as the psychomotor responses or reflexes in relation to flying.

I show you here the method which was first employed because it had been studied by psychologists in relation to selection of individuals for human activities apart from flying. It is the study of what are known as the simple visual, auditory and tactile reflexes. In testing these simple reflexes the subject is asked to depress or release a key when he sees a light (the visual reflex) or hears a noise (auditory reflex) or feels a tap (tactile reflex).

In what are known as choice reactions the subject has to depress a special key when he perceives the stimulus, *e.g.*, key A when he sees a light, key B when he hears a noise, key C when he feels a touch, or only using one key he may be told to depress the key only when he sees a white light and not when he sees a red or a blue one.

It was believed that good pilots always had quick responses, whereas less satisfactory ones had slow ones.

This method of selecting pilots has never been adopted by the British, although the method has been tested out. As the result of the experiments conducted at a

training station here, the conclusion was reached that there is really no definite relationship between quickness of the responses and aptitude for flying. From a purely medical point of view the results are of some value, since consistent responses indicate stability of nervous control, while erratic responses indicate instability. That is a point of prime importance to be remembered in regard to all tests such as these, namely, consistency of response, be it relatively quick or relatively slow, is better than erraticness of response.

Now let us consider wherein the method fails. I think you will agree with me that the first fundamental objection is that it is one thing to make a simple movement such as depressing or raising a finger in response to a stimulus—another thing to perform delicately co-ordinated movements of the limbs in response to such a stimulus. That is actually found to be the case in practice. Five men, for example, will quickly depress a key in approximately the same time (20/100ths of a second) in response to a visual stimulus, but if asked to perform a definite combined arm and leg movement in response to such stimulus they will give times varying as widely as from, say, two to five seconds. In other words, the method I have shown you fails because while testing perception it does not adequately test performance.

Experience also shows other drawbacks. For instance, the highly-strung individual who may give very quick responses is often the type who is most likely to develop " nerviness " under strain. Again, the method makes no allowance and affords no real indication of improvability by practice. By this I mean that although the good pilot may possess quick perception, he undoubtedly develops increased quickness of perception as he acquires experience, just as a batsman or a golfer develops " eye " by practice.

The results show that the British were right in adhering to the view that a history of all-round aptitude for sports and games was of more importance in selecting a pupil for flying than was testing his psychomotor responses on one occasion only, and that often a nerve-trying one. It is one thing to put up a good performance at such a test when much depends upon it, as, for example, admission to a commission, and another to do well when one is not in the position of examinee. And in this connection it must be remembered that the pilot is, generally speaking, the master of his fate in a machine.

Although the above method was not so helpful as was at one time stated, it is obvious that a method in which performance of the movements of flying in responses to certain stimuli might prove of value in picking out the subject who was likely to manifest aptitude from those who would not, even when due allowance was made for improvability by practice.

With this object in view Flight Lieutenant G. H. Reid was asked to devise an apparatus on these lines for the Royal Air Force Medical Research Laboratory. In this, I am glad to say, he was successful, and the apparatus has now been put to test both in the laboratory and at a flying training station.

Before I show this apparatus to you I wish to make it clear that this apparatus cannot teach a man to fly, and although, as we shall see, practice upon the apparatus may improve his aptitude for flying, it will never teach him to fly. If I have made myself clear earlier on, it will be seen at once that it can never give him the " feel " of the machine in flight; it cannot teach him in response to the sensations encountered in the air to perform consciously or automatically those movements which make for safety in flight. But what I hope to show you that it can do is :—

(1) Test the potential aptitude for controlling the control column by delicate co-ordinated movements of the arm;
(2) Test also the aptitude for working the rudder bar in similar fashion; and more important still,
(3) Test the aptitude to perform the combined movements of arm and leg necessary for the various movements of flying.

In addition, it was believed and hoped that such a machine would enable certain subjects to acquire increased aptitude by practice, as well possibly of indicating the type of a machine on which he is likely to be most proficient. From the service point of view this last point does not arise, but the fact remains that although a man should preferably be able to fly all types of machines, there are some men who will never have sufficient delicacy of arm and leg movement to fly single-seater machines with their optimum performance, although they could quite easily do this in respect of a somewhat heavier two-seater machine.

Dealing first with the laboratory work, I show you some curves which have already been published elsewhere in your journal. I think you will agree that there is a marked difference in the curve given by the successful pilot and that given by an unsuccessful one.

Although very interesting, this would not be of particular value—the question is, can the apparatus pick out at an early stage subjects who are likely to be successful in flying from those who will not?

To do this, the apparatus might be called upon to function in two ways, either (1) to afford such information by one test on the apparatus only, or (2) to afford such information by periodic tests during flying instruction to see whether the written records on the apparatus agree with the instructor's opinion as to the pupil's potential aptitude and rate of progress during instruction.

The first method, I think you will see at once, has this drawback, that it does not allow for improvability, although of course it is conceivable that a subject might write such a bad initial curve—like that you have seen—that it might be possible to say at once, that given as much practice as he wishes, this subject will never make a satisfactory pilot. On the other hand, the second method has much to recommend it. It allows for improvability by practice and enables several records to be taken of a subject before a definite judgment is formed; it also enables his written records on the apparatus to be compared with his instructor's reports.

I now show you some results connected with the definite progress of pupils at a Flying Training School.

From the preliminary records an endeavour was made to assess the potential aptitude of the subjects. At the end of their Avro training, of those graded as "promising," over 80 per cent. turned out on instructors' reports to be above the average, of those graded as "below average, unlikely to become satisfactory pilots unless great improvability shown," approximately 77 per cent. were subsequently graded by their instructors as below the average. Of the intermediate group graded "average, progress depending upon their improvability," the reports of the instructors coincided closely with the degree of improvability shown. Thus, when the results upon the apparatus at the end of their Avro training were compared with the instructors' reports, it was found that there was agreement in 80 per cent. of the assessments of the ability of the subjects as pilots.

Records Nos. 1 and 2 show two pupils of promise. The promise was fulfilled. Record No. 3 shows an average pupil. Owing, however, to his great power of improvability he made rapid progress and went solo in about a week after 3 hours 40 minutes training. The last part of the record (reading from left to right) shows the very fine curve this pupil wrote immediately after going solo. He had practised on the apparatus for 2 hours 40 minutes. Record No. 4, as an initial record, shows lack of promise, as does Record No. 5. Both these pupils were eventually turned down by the authorities as unlikely to become successful pilots. They exemplify the fact, therefore, that allowing a sufficient margin for improvability there are certain subjects who make so bad an initial record that it is not in their interests or those of the State to undertake their training. Record

No. 6 shows the curve of No. 4 after two months' flying training; it will be seen that he showed no improvability; in fact, the curve is worse than the initial one.

The experiment at the Flying Training School also showed that the apparatus may profitably be used as a practice apparatus to endeavour to eradicate definite flying faults observed in the air.

In regard to the value of the apparatus for training flying aptitude generally, it was found that the group of pupils who practised upon the apparatus on the ground went solo at an earlier period in their training and consequently the output of pilots per month among them was much greater in the first months of flying instruction.

Such are the results of the first experiment at a Flying Training School, and I think they may be regarded as encouraging. The experiments are still being continued, and the results must be awaited before a definite policy can be advocated as to the most profitable method of use of the apparatus, but that it will be used is, I think, certain.

I wish to emphasise the fact that this apparatus has hitherto only been on its trial, and that in arriving at the results instructors were kept in complete ignorance of the apparatus records. These records have not been used to influence the career for good or ill of any of the pupils who have been tested thereon. They have been judged entirely on the reports of their instructors in the air, though it is conceivable that, when fully tested out, the indications of this apparatus may be found to be sufficiently reliable to merit being taken into consideration at an early stage of the pupil's career.

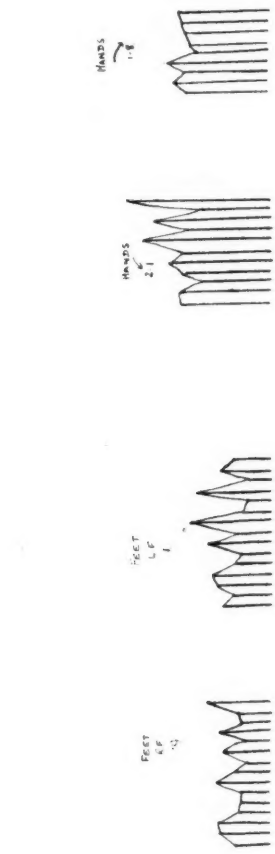
Returning now to the machine, just as I have advocated so far as possible standardised position of the means of perception, so I would point out that it is in the interests of the pilot to have a standardised position and method of working of the various controls. This is necessary on account of what is known as "liability to regression." I can make this clear by the following illustration:—If one has been driving a car with the hand brake on the right, and then starts driving a car with this brake on the left, then until one is accustomed to the new position, in a moment of sudden emergency necessitating quick application of both brakes, one is liable to endeavour to seize the hand brake on the old right-sided position rather than on the left-hand side. So with the aeroplane.

For example, it is advisable to have so far as possible a standardised position and method of control of the petrol system, so that in an emergency necessitating the cutting off of petrol this may be readily performed, the hand, so to speak, almost instinctively seeking the correct position to perform this act. An instance of the value of such standardisation, which has already been more or less accomplished, is the direction of working the throttle control. In time past, the movement which closed the throttle on most machines opened it out on another type. This constituted a serious danger to the pilots in an emergency.

With all the manifold activities which a pilot may be called upon to perform, I think it will be agreed that the easier of accomplishment we can make these the greater the safety, and I advocate that this medical aspect of the subject be borne in mind as far as possible.

Finally, I would plead for the maximal possible comfort and protection of the pilot in the design of the machine. In these days of long flights I feel that more could be done in providing padded backs and seats, padded arm rests and ample leg room to afford comfort during such flights. Also, since head and face injuries are very liable to occur in accidents, more could be done in the way of padding the cockpit in such a manner as to mitigate the severity of any injuries sustained.

I noticed at the recent aviation exhibition in Paris that the French designers and manufacturers are beginning to deal seriously with both these points, and I hope and feel sure that the British will not lag behind.



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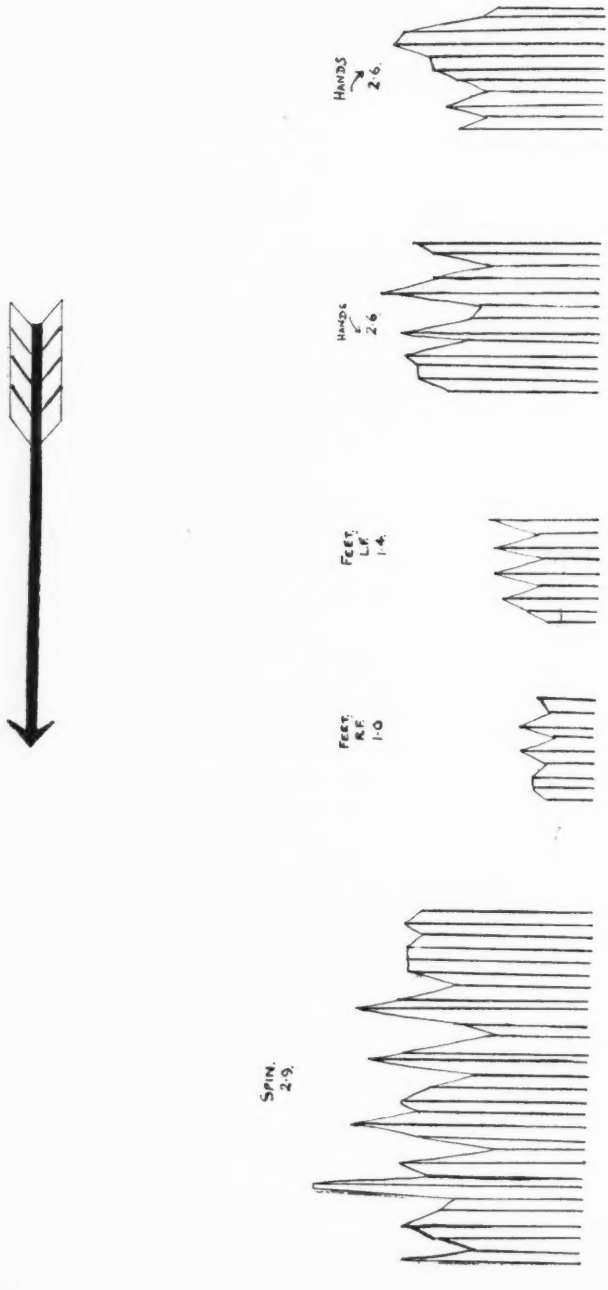

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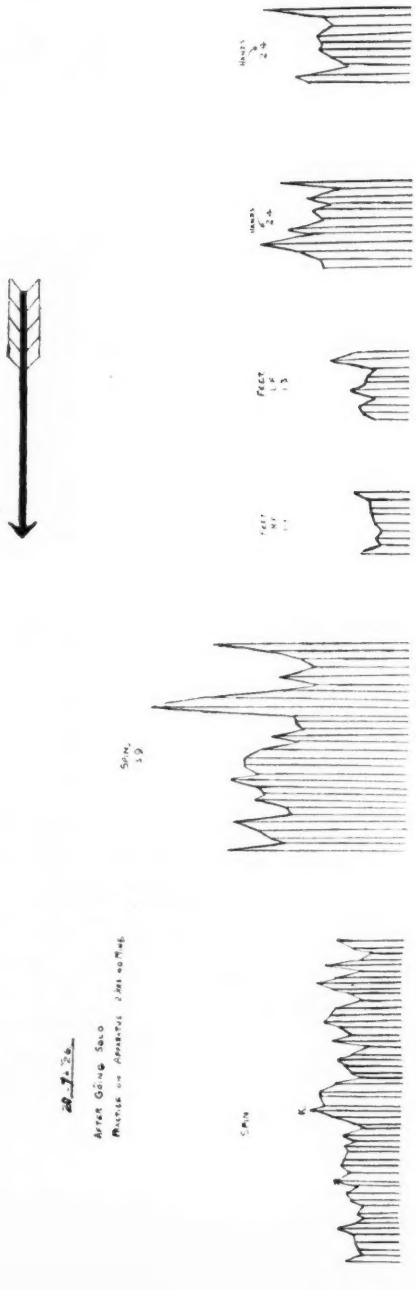

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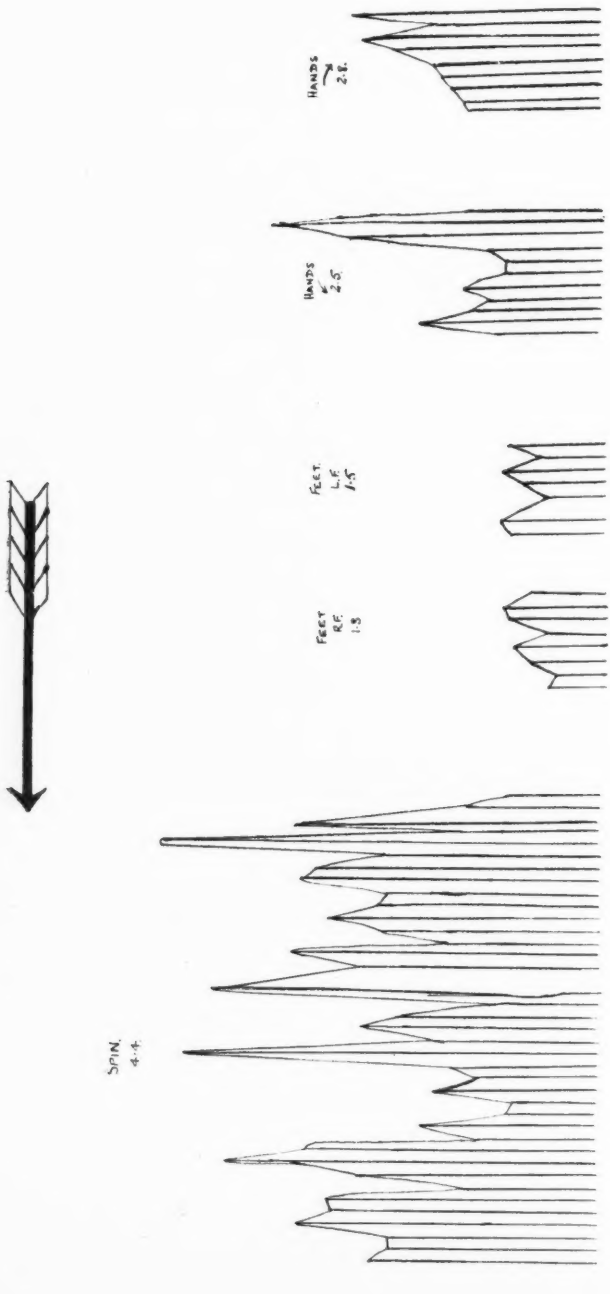

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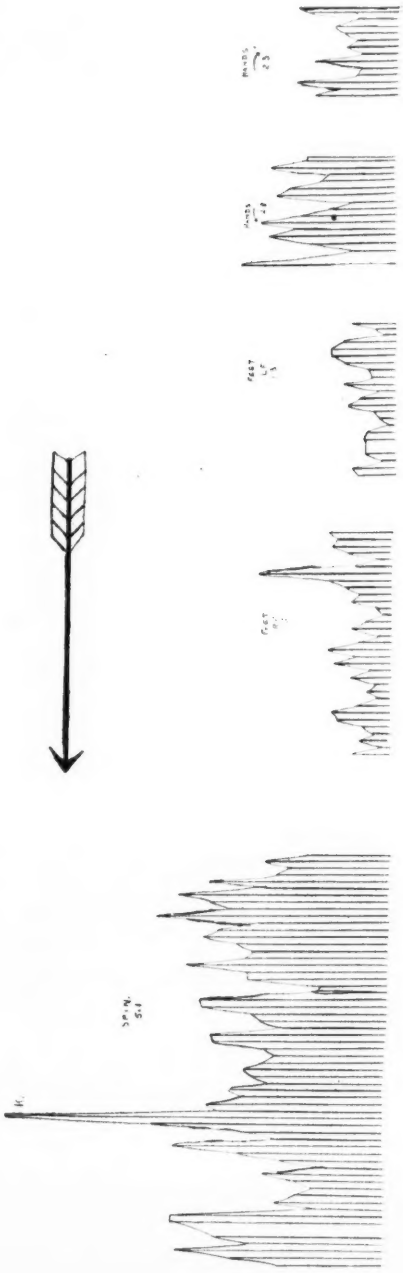

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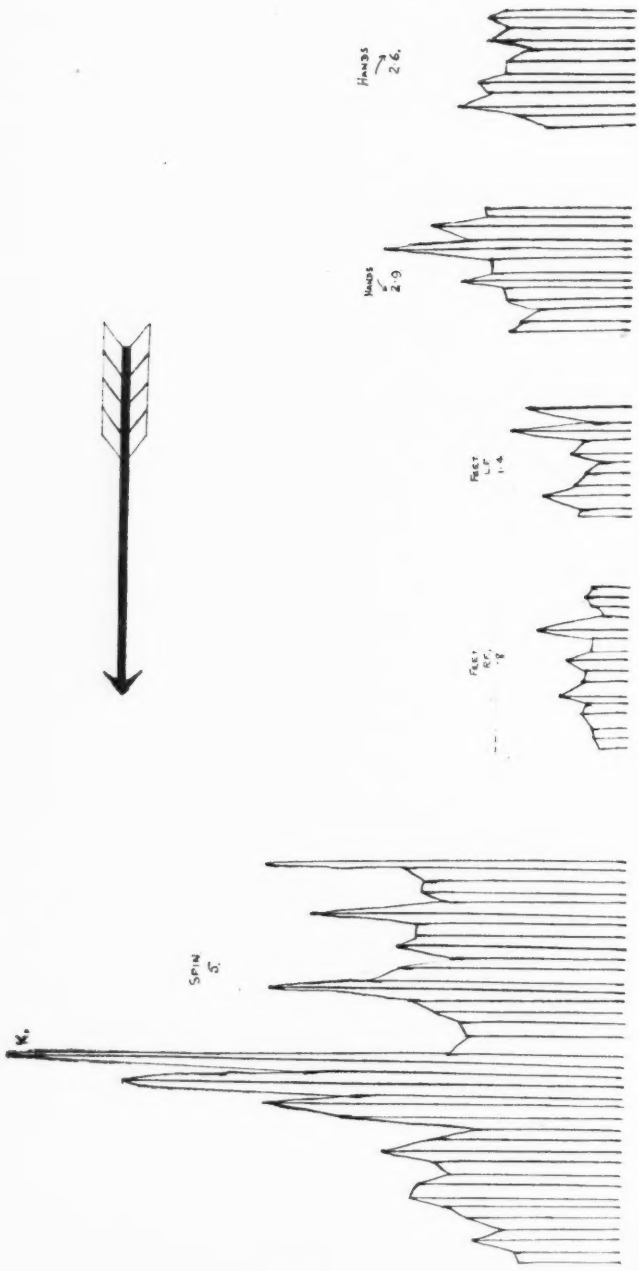

RECORD No. 6.

Discussion

Colonel The Master of Sempill : I am sure that you have all listened to this lecture and witnessed the demonstration with great interest. Personally, I am convinced that the apparatus demonstrated can improve even the best pilot, but I cannot conceive of any apparatus which could improve the ability of Group Captain Flack as a lecturer. He has delivered an admirable lecture. Our thanks are due to him for that, and also to Flight Lieutenant Reid for demonstrating the apparatus, and to the two other gentlemen for their performance on the apparatus.

Captain Sayers : I think this is one of the most interesting lectures that I have heard from the Society for some time, and I have great difficulty in repressing my admiration of the ingenuity of Flight Lieutenant Reid's control indicator which we have just seen demonstrated. It undoubtedly does seem to measure with uncanny accuracy whether a man has any chance of becoming a good pilot. At Wembley, when the apparatus was shown there, Flight Lieutenant Reid showed me the chart made by Mr. Sopwith, who had not then flown for about ten years, and it was quite unmistakably clear that he was a pilot, and a good one at that. There were other charts equally interesting.

At the same time I should like to inquire into the validity of some of the written assumptions with regard to the written records of this instrument as definite and certain indications of the degree of automaticity a man is likely to show. Group Captain Flack says that, broadly speaking, the degree of automaticity differentiates the experienced from the inexperienced one. That is undoubtedly true. The man who is used to flying an aeroplane does things automatically that the man who is not used to flying has to stop and think about.

Group Captain Flack gave us the illustration of a man who is used to driving a car with a left-hand brake, and regresses in a moment of emergency, yet he appears to favour an increase of automaticity. Is it not conceivable that one can have too much automaticity? I think so. I recall in the early days of flying a certain pupil who went to the Bristol School. He was of an advanced age for flying in those days, about 35, and considered to be an extremely poor pupil, taking a long time to learn to fly, but at the end of some considerable period—something over a year—he developed into a star turn instructor, and he continued to fly as an experimental and test pilot for a number of years.

I should like to ask whether in Group Captain Flack's opinion it is not possible that in some cases this apparatus would turn down a man as unable to fly because he does not abandon himself to flying automatically, but tries to control his operations as far as possible. This method would slow up his actions, and he would not easily develop the habit of flying, but he might eventually become a better pilot than the average.

Squadron Leader Howett : I would like to say from practical experience that I consider control indicators are absolutely necessary for flying in fog, clouds and at night, and that these instruments should be placed immediately in front of the pilot.

The success of the Reid control indicator is due to the fact that all the three necessary movements are combined in the one instrument, and the information conveyed by electric lights. I have tried many types of turn indicators, but none gave such good results or the same degree of confidence as the Reid control indicator, and I quite agree with Major Brackley in his remarks on this instrument. It is essentially a pilot's instrument.

About five years ago I tested various kinds of turn indicators, but few of the inventors had grasped the point that it is practically impossible for the pilot, in bad weather, to gaze all over the place to consult his instruments. The majority of pilots agree from the practical point of view that this instrument is what is

required, and is by far the best for practically solving the problem of flying and keeping course in bad weather.

Captain R. O. KING: I am not qualified to express an opinion about the apparatus as a means for determining the possible flying capability of a prospective air pilot. The value of the apparatus in that respect is best judged by the data submitted by Group Captain Flack. My trial of it gave me the impression that it tested sureness of movement and judgment. The combined operation of the rudder bar and stick required mental concentration, and I did not find it easy to accomplish this movement correctly and at all quickly.

One point that struck me when the discussion turned on the position of instruments was that the ordinary typewriting machine offered a convenient illustration of standardised placing. Imagine the loss of automaticity that would be suffered by the typist who found the various characters of her keyboard changed from their familiar positions. I should have thought that the need for the standardisation of the position of instruments in an aeroplane did not need argument.

Wing Commander T. R. CAVE-BROWNE-CAVE said: A discussion should, I think, be critical, but criticism of a lecture such as this is not easy.

The performance of each pilot with the apparatus was greatly influenced by the Klaxon. It appears to me probable that the conditions in an aeroplane would produce an even greater difference, and might greatly modify the order in which individual pilots would be classified.

While I agree that the apparatus is admirable for pilots to practise on, with a view to developing quickness and accuracy of touch, I think it is liable to neglect exactly that characteristic which is most important in a pilot.

It is, I think, the man who can perform in an aeroplane under trying circumstances, just as well as he would in the apparatus, who will make the really good pilot. It may be that the change in performance produced by sounding the Klaxon horn is some indication of the change between performance on the ground and performance in the air, but I feel that the relation is doubtful.

I entirely agree that the way in which a man performs at a great variety of games which require judgment and dexterity is an excellent index of what is required for R.A.F. personnel.

The extent to which a very simple performance can be upset by nervous disturbance is clearly shown in revolver shooting. The first shot which a novice fires is nearly always a remarkably good one. After that the shooting becomes extremely wild. If without his knowledge one of the chambers of the revolver is left empty, one sees exactly the reason of the bad shooting. As he pulls the trigger for the empty chamber he dips the point of the revolver impulsively downwards, in anticipation of the recoil and noise which he thinks will follow.

With regard to the question of comfort, I certainly agree that a really comfortable position is conducive to increased endurance. There is, however, another aspect illustrated by the fact that the Quartermaster who controls the course of a ship at sea is never allowed to sit down, because it is feared that his attention might relax.

When watchkeeping in the engine room in the Tropics, personal fatigue is such that there is a strong temptation to allow the men to sit down, but such a course would be almost certain to result in their going to sleep.

On long-distance flights many pilots experience difficulty in keeping awake unless they are very fully occupied with difficult navigation, or something else to retain their attention. It appears possible, therefore, that increased comfort might have the effect of increasing the difficulty of keeping awake.

Major C. C. TURNER: I am very glad that this discussion has not been confined to the apparatus, as I want to raise a point on which I have thought for many years. Many accidents are no doubt due not so much to the pilot's lack of skill

as to lack of judgment, and perhaps not so much to lack of judgment as lack of moral character. So many accidents take place immediately after the machine has left the ground; the engine fails, and the pilot does not do the right thing. Group Captain Flack's paper has rather inspired me with the hope that since very great advances have been made on the physiological side it may be possible for the faculty to consider also what might be done on the psychological side, and then you could apply tests for potential pilots not merely to prove quick response of hand to brain, but to enable you to know whether a pilot would keep straight on, and perhaps make a " pancake " landing, rather than attempt an impossible turn. I would greatly prefer to go up with a pilot suffering from myopia or astigmatism if I were assured that if the engine failed just at the ascent, where there was not room to turn back, he would resist the temptation to turn and would make some sort of landing outside the aerodrome.

Mr. C. G. COLEBROOK: So far the discussion has dealt with the technical merits of the apparatus, but I should like to draw attention to a wider point of view. I have just been listening to the debate in the House of Commons on the Air Estimates, and there the Prime Minister dealt with air accidents. He said that he had personally investigated these and was convinced that everything possible was being done to reduce accidents, and that the whole subject was constantly under review. My mind reverted to this lecture and the apparatus which has been demonstrated here to-night, which, it seems to me, will have a distinct bearing on the question of accidents in the Air Force. The expansion of the Air Force now is gradual, but if it had to be quickened up and a number of candidates had to be examined, then the apparatus should be very valuable indeed. It should eliminate at the beginning a certain number of people whose record was such that they were not likely to make successful pilots or else would demand such close attention on the part of the instructor that it might not be expedient to undertake their training. At such a time there might be such pressure that it would be impossible to give the close attention to the tuition really required in their cases.

The effect of practising on the apparatus is to increase the rate of progress, and that is most valuable. I see that it is not claimed that this apparatus will give any definite statement that this man will never make a good pilot and that man will, but it seems clear, with further experience at the flying training schools, that so much agreement with the opinions of the instructors will be found, that by its use it will be possible to eliminate candidates who are never likely to be satisfactory pilots. This should mean that Royal Air Force accidents will not increase in the same ratio as the expansion, but ultimately should be less—a most desirable thing not only from the point of view of human life, but from an economical standpoint as well.

Mr. GRIFFITH BREWER: I was very interested to hear the reference to semi-circular canals, because that was a fact that was known to Maxim. He designed an airspeed indicator which would measure the speed of an aeroplane by the force of the air received on a disc. Later on that fact was forgotten, and in the early days of the war airspeed indicators were issued which were dependent on gravity control. A gauge was used with a U tube receiving the pressure of air from a pitot tube, and the amount of indicated speed varied with the weight of the fluid in the U tube. If you dived, the gravity weight of the liquid in the tube became less and a higher speed was then shown than was actually being flown. I do not know whether any accidents occurred through the use of these gravity-controlled instruments, but very soon an indicator was designed by Colonel Ogilvie, and after that all the standard instruments were of spring-operated type.

There is one other point. I am afraid I am being rather historical. In 1914 at the Wright School at Dayton we used to practise on a machine to enable us to learn instinctively to operate the lateral control. The machine was mounted

on a fore and aft pivot, and you were seated above the centre of gravity, so that if you left the machine alone it would fall one way or the other. There was a little motor on the ground which ran an endless cord, and by operating the lateral controls you could clutch the up or down running cord, and in that way restore the machine to a level position. We used to practise with our eyes open and with our eyes shut. I was practising with my eyes shut one day, and opened them because the people round were laughing, and I found that Orville Wright was holding on to the machine. I was trying to restore loss of balance, which did not exist because the machine was held stationary. This illustrates that it requires actual vision to maintain balance on an aeroplane without instruments.

Dr. ARTHUR HAYDON: The automatic action of the brain was mentioned with regard to rapid movements. That has been exemplified in road accidents and railway accidents. This was exemplified in a remarkable way by the engine driver of the Salisbury express, as it was clearly proved that owing to the automatic action of the brain he quite forgot that he had already passed through an important station. Therefore many aeroplane accidents may be due to a condition of temporary unconsciousness, however induced, together with too much automatism. It occurred to me that it might be doubtful as to whether to make the pilot's movements more standardised, or whether to make the levers different in different machines so that conscious control was maintained, and so eliminate the possible automatic action of the brain. In high speed travelling the automatic action of the brain is rather an advantage. Therefore I suggest that some apparatus might be devised so that during his training the pilot should have to manipulate completely different levers corresponding to those which he would have to use in various types of aeroplanes.

With regard to noise and its effect on the drum of the ear, naval officers do not notice the noise of guns going off; they become so used to it. It is quite possible for the drum of the ear to become so accustomed to noise by repetition that I should not think there could be any great harm, provided that it be not too prolonged.

Colonel THE MASTER OF SEMPILL: Before asking Group Captain Flack to reply to the discussion I should like to put one or two questions to him.

The association between Group Captain Flack and Flight Lieutenant Reid has been a very fortunate one, as it has led to the production of the apparatus that has been demonstrated to us this evening. The uncannily reliable results that this apparatus has been proved to give are touched upon in the paper, and there can be no question that it has far-reaching possibilities. It inevitably appeals to those interested in the training of pilots whether for civil or military purposes. Flight Lieutenant Reid will be better known to you as the inventor of the Reid turn indicator, which has been referred to in the discussion.

The lecturer has very rightly emphasised the necessity of such an instrument, and the Air Superintendent of Imperial Airways has told us that Reid turn indicators are used exclusively on Imperial Airways machines.

I should like to ask Group Captain Flack if he has any experience as to how the reaction apparatus stands up in ordinary use at an air station. Is it economical and easy in operation? It is a pity that the full details of the series of tests that have been carried out at one of the principal training stations cannot be made available, but it is clear that these results were amply and independently supported by the opinions of the flying instructors. It is of particular interest to know that during the time this apparatus has been on its trial no attention whatever has been paid to the results obtained when assessing the abilities of the pupils. In fact, it appears that the instructors were not aware of these results, and the agreement reached is all the more remarkable. The principal advantages that are to be gained may be enumerated as follows:—

1. You will be able in the beginning to weed out those who would never make pilots.
2. You would be able to improve the others and speed up training.
3. You would be able to reduce the number of accidents, thus obtaining great economy and greater efficiency.

It would seem on the present basis of training in this country that the use of this apparatus could effect a yearly saving of a quarter of a million sterling. The need for economy is always with us, and this factor alone would seem to furnish more than an ample argument for its adoption. I would ask the lecturer if he is in agreement with these figures.

In regard to the question of comfort I must beg to differ most emphatically from the remarks made by Wing Commander Cave-Browne-Cave. The duties of a pilot of a heavier-than-air craft and of the Quartermaster of a ship cannot be compared. The duties of a pilot are more arduous and his movements are far more restricted. I think there is everything to gain by paying great attention to comfort, as a pilot if made comfortable will be able to perform his duties more efficiently and be far less fatigued on their conclusion. I would like to pay a tribute to the valuable work the lecturer has been doing not only in directing attention to this important point, but by the institution of researches that have had a considerable influence on the solution of many of the problems involved. Personally, I have made a number of tests with various types of seats differently adapted with and without arm rests, etc., in flights of six and seven hours' duration, and the difference in one's physical condition during and after such a flight where the maximum possible comfort is obtained is different indeed from that wherein little attention is given to this point.

Reply to Discussion

Group Captain Flack: In respect of the training results on the apparatus, the results given show the large amount of agreement between the initial records of the apparatus and the opinions of the instructors. I can elaborate somewhat upon the records obtained after their Avro training when compared with the instructors' reports. It was found that there was agreement in 80 per cent. of the assessments of the ability of the subjects as pilots when classed as A—exceptional; B—above average; C—average; D—below average; E—unsuitable. In reality the results are better than the figures show, since one could never expect to get absolute agreement, if only because the apparatus does not record the same. The apparatus will indicate that a man is good, but the instructor will report that he is average, not because his flying is not good but because he may be over-confident. In the assessment there was never a discrepancy of more than one degree. In regard to making these assessments it is to be noted that Flight Lieutenant Reid had control of the apparatus, but I made the assessments and I have personally never met the pilots. These assessments were then compared with the instructors' reports in conjunction with the Commanding Officer, and there was the amount of agreement indicated.

Major Brackley tried the apparatus some time ago, while it was slightly more sensitive than at present; his was a good, steady curve. Two well-known pilots of Imperial Airways have put up curves which rank with the best ever recorded, although they are generally flying relatively heavy machines.

With regard to noise, you get used to it, but if excessive, certainly contributes to the induction of fatigue. When deafness is caused it appears to be more a question of where the pilot is seated than anything else. I have tried to get special flying caps and ear defenders, but it would appear that altering the position of the pilot with regard to the propellers is the most hopeful solution.

In reply to Wing Commander Cave-Browne-Cave, the apparatus helps to give indication about aptitude for games. A golf champion wrote records of certain movements and from them one could tell where his weakness lay. It has also been tried to test motor drivers, and the bad drivers were picked out. The principle of the apparatus could also be adapted to other needs.

Relative comfort is a most important point in flying because the pilot has all the disadvantages of the sedentary position to overcome without the aiding effects of exercise. A pilot cannot get up and stamp, and there is seldom room in which adequately to stretch himself. The pilot frequently sits on a hard seat in a cramped space, which not only militates against good performance but also serves to induce fatigue. If one can only make him reasonably comfortable it will improve his efficiency, especially after journeys of four hours and so on.

In reply to Major Turner's query as to tests for judgment, it is difficult to devise these. I have been looking into these so-called tests for judgment, but it seems to me, with regard to the well-known lack of judgment of pilots turning back down wind to aerodromes when engine failure occurs, that the only thing is to keep on drumming into them while they are being trained what it is they ought to do in such an emergency.

Captain Sayers asked whether there could not be too much automaticity. I do not think so; all machines should be adapted to conform as far as possible to the automatic movements which a pilot acquires, especially during training. As I have said, I would have all controls work as far as possible with the same kind of movement in all apparatus, etc., placed in relatively the same position and operated in the same kind of manner.

In reply to the Chairman, I think Flight Lieutenant Reid can report better than I as to how an apparatus stands up at a station. I believe it worked very efficiently and cost very little to run.

Flight Lieutenant REID: There is no difficulty in working the apparatus as it was designed to be automatic and foolproof. The pupils at the training schools were instructed in the use of the apparatus, and worked it themselves. There is no need for anyone to be present, as the interior switch enables the subject to actually test his own rate of progress.

The accumulators were changed fortnightly as a matter of routine, but each accumulator would last easily three weeks for each fifteen pupils under training. A greater number of pupils than this becomes rather unmanageable on one apparatus if the greatest efficiency is required. The upkeep is the changing of the accumulators and the charting paper.

Group Captain FLACK: In regard to the Chairman's estimate of the saving of cost, it is obvious that there is a big wastage in training all people who are not suitable. I know nothing about the costs of training, but this apparatus would save instructors' time, damage to the machines, use of machines by men who are going to be no good, accidents and medical treatment. I think it possible, therefore, that the Chairman's estimate is not too high.

THE REGULATION OF AIR TRAFFIC

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1 The Need for Investigation

Valuable lives and thousands of pounds worth of equipment are lost in collisions each year.

The graphs of civil aviation traffic[1] show that an accident in May of 1922 was followed in June by a drop in the average monthly passenger traffic of 325 passengers. A more serious accident in May, 1923, was followed by a drop in traffic during May and June of 750 passengers.

There is thus every incentive to minimise the risk of collision as far as possible, if only from an economical standpoint, as apart from the humanitarian.

Under the existing regulations there is danger of collision not only from all points of the compass in a horizontal plane—and, even at sea, with rules based on a thousand years' experience, collisions are all too frequent—but from every conceivable direction of which the pilot is the unfortunate centre.

Rule of the Air No. 29 is perhaps the best exposition of the present state of affairs in air navigation. It says, "Every aircraft in a cloud, fog, mist . . . shall proceed with caution. . . ." I submit that no aeroplane travelling through a cloud at 100 m.p.h. can "proceed with caution." If there is another aeroplane in that cloud, it is luck and luck alone which will prevent a collision under the existing regulations.

When one investigates the rules of the air, one is struck by the outstanding fact that they are, in effect, nothing but the rules for maritime navigation on which have been superimposed rules made to cover the "dangers" arising from additional movements in a third dimension. No attempt appears hitherto to have been made to consider the three dimensions simultaneously.

It is noteworthy that the main danger of two-dimensional traffic actually lies in the impossibility of using the third dimension.

The additional "dangers" which the rules are framed to overcome entirely disappear when the subject is viewed in the broader sense. It is proposed to show in this paper that not only is the third dimension far from causing additional dangers, but that if properly considered in the framing of the rules, it allows most of the possible causes of collision to be eliminated.

2 Safety on Cross-Country Flights

Suggested Rule of the Air (1)

I suggest that as a fundamental principle it is essential that every possible compass bearing has one height only and that in a predetermined vertical zone, along which a course may be laid.

The degrees of the compass in combination with the English system of measuring height in feet, fortunately lend themselves most admirably to inclusion in a formula which will give the desired result, *i.e.* :—

> "The layer of atmosphere between the heights of 2,000ft. and 5,600ft. as shown on an aneroid uncorrected for local temperature and pressure conditions will be known as the 'First Traffic Zone.'

[1] *Proc. R.U.S.I.*, Vol. LXXI., No. 482, para 147.

" The altitude of an aircraft flying in this Zone will invariably be determined by its course and will be 2,000ft. + the magnetic bearing of the aircraft's compass course[2] in degrees multiplied by ten and expressed as feet.

" When descending from the Traffic Zone the altitude will be determined as laid down in Rule of the Air (3)." [3]

e.g., (i) Aircraft travelling W. to E.
Course 90°
Height = 2,000 + 90 × 10
= 2,900 feet.

(ii) Aircraft travelling E. to W.
Course 270°
Height = 2,000 + 270 × 10
= 4,700 feet.

This rule would ensure that aircraft proceeding in any direction whatsoever would be separated from aircraft proceeding in an opposite direction by 1,800ft.; they would be separated from aircraft proceeding at right angles to their own course by 900ft.

In other words, on a straight course *a pilot need only look ahead* to avoid a collision; if he alters his course to port he need only look downward to port; if he alters his course to starboard he need only look upwards to starboard. The design of civil aircraft is thus freed of many existing restrictions as to the position of the planes in relation to the pilot and the fatigue of pilots on long cross-country flights is greatly reduced.

It will be seen that the proposed traffic zone lies between 2,000ft. and 5,600ft. 2,000ft. is chosen as the lowest height as this is already fixed [4] as the minimum height at which cross-country flights may at present be made. 5,600ft., the maximum height, is obtained by multiplying the greatest number of degrees in the compass (360°) by ten and adding the result to the minimum height.

The adoption of the figures in Rule 1 have been considered in their relation to prevailing winds at various heights, and from meteorological data available it seems improbable that there would be any advantage gained by altering the course at the zero height from a bearing of 0°. Certainly much would be lost in reducing the simplicity of the formula, were this done.

Although pilots could not select their height under these regulations, it should be noted that they could arrange their times of departure so as to coincide with the times of the best prevailing wind during the day at the particular height required under the regulations for their courses. Civil aviation firms would amend their time tables accordingly.

This data compiled and amended yearly for every aerodrome should be available to pilots, and the meteorological data board should have one panel giving the required information. It might be tabulated as shown in Appendix " A " to this paper.

When flying over open stretches of water or mountainous country, it is for consideration whether a second Traffic Zone above the first be introduced. This should end 3,600ft. above the first in order that the zones are continuous and aircraft can pass from one to the other with safety. The only basic alteration required to Rule 1 would be the substitution of 5,600ft. for 2,000ft., and 9,200ft. for 5,600ft. where those figures occur.

To avoid confusion as to whether a pilot should fly in the first or second Traffic Zones, aeronautical maps could have this information printed inside each

[2] *i.e.*, not necessarily the bearing of the aircraft's course over the ground.
[3] See para. 4.
[4] K.R. and A.C.I., para. 654 (b).

square formed by the lines of longitude and the parallels of latitude which are usually drawn at every fifteen minutes' interval.

The squares could have either "1.T.Z." or "2.T.Z." printed centrally in large red skeleton letters, or the words "First Traffic Zone" or "Second Traffic Zone" could be printed along every line of latitude and longitude so as to be read from all four directions outside the square, *i.e.*, they would be legible even were the map oriented in such a way that the ordinary printed information was upside down to the pilot.

Appendix "B" illustrates the method of marking adjacent squares, one of which contains a mountain of 6,500ft.

To correlate the aneroids of aircraft ascending from aerodromes of different heights above sea-level, it will become essential for all aneroids to be set, before leaving the ground, at the height of the departure aerodrome above or below sea-level.

The necessity for this will, however, cause little, if any, detraction from the value of the instrument to pilots.

A pilot, other than one learning to fly, rarely, if ever, consults his aneroid once he is below 1,000ft.; his sole attention is given to the approach for his subsequent landing. During eleven years of practical experience in flying, I have not once known a pilot go to the trouble of consulting a map for the purpose of setting the pointer of his aneroid to the height of the aerodrome at which he intended to land. This is solely because experienced pilots do not rely on their aneroid to assist them in judging their height from the ground when coming in to land. The value of the instrument for pupils will not be lost, for, flying only in a scheduled area reserved for training schools, etc., outside the Traffic Zone, their aneroids may be set to zero as at present.

Objection may be raised and it is as well to state here that the type of aneroid now in general use would need very slight modification in its design to give two readings, *i.e.*, to show (1) the height above sea-level and (2) the height above aerodrome level. Several methods by which this could be done readily suggest themselves. It is even probable that the existing instruments could if necessary be converted, but it is not considered that the occasion for the modification will ever arise.

A notice showing the height above or below sea-level of each aerodrome should be displayed on all meteorological data boards. Not only would the information be available for pilots using the Traffic Zone, but it would be of value also to pilots flying in the other zones in making more accurate use of the meteorological data provided. Quite apart from the matters under discussion, it is considered that the suggestion, although relatively unimportant, is worthy of adoption on its present merits. Usually, to find the height of one's aerodrome it is necessary to follow the devious courses of almost invisible contour lines on a map until the very minute figures giving the required information are found.

3 Safety at Aerodromes (Descents)

So far we have dealt with the safety of aircraft actually on a cross-country flight, but there still remains the question of how to pass through the traffic zone and how to ascend and descend to the required height. Normally this will be done at an aerodrome, and it is here that special provision must be made owing to possible congestion of traffic.

The changes of courses and heights on cross-country flights would be few and probably never greater than through an angle of 45° (450ft.). Furthermore, these changes would be gradual.

At an aerodrome, however, ascents and especially descents involve more rapid changes of course and height; as a refinement to the proposed Rule 1 it is desirable, therefore, particularly at aerodromes such as Croydon, to provide a path

for descending aircraft which cannot possibly cross the paths of aircraft in the Traffic Zone.

We are faced with the fact that there is an infinite series of parallel paths at the same height any of which may be in use. Each path lies on practically the same bearing, and it is obvious that while these conditions obtain, there is no method at present by which the paths can be traversed in a vertical direction with absolute security against collision.

Suggested Rule of the Air (2)

But if the paths of aircraft in the Traffic Zone be made to converge over the centre of the aerodrome, a method, which will be explained later, becomes possible. The following rule would ensure this convergence :—

> " Aircraft flying in the Traffic Zone will either pass directly over the centre of an aerodrome or will avoid the aerodrome by a distance of ..... miles."

The paths of " cross-country " aircraft passing over an aerodrome would thus form a double-threaded helix which may be called the " Traffic Spiral " whose centre is vertically above the centre of the aerodrome. The radius of the helix is arbitrarily determined as the maximum radius of the larger of the two Archimedean spirals, one of which is traced by ascending aircraft which have the slowest rate of climb (*i.e.*, those with a maximum ceiling of about 6,000ft.) and the other traced by descending aircraft which are known to have the flattest gliding angle.

This radius will determine the distance mentioned in the proposed Rule 2.

The main danger at an aerodrome lies in the possibility of an aircraft descending the traffic spiral colliding with one ascending the spiral.

Suggested Rule of the Air (3)

A second spiral pathway concentric with the first but starting at 90° farther round the circle can, however, be reserved for descending aircraft by the introduction of the following rule.

> " When it is desired to descend from the Traffic Zone over an aerodrome an aircraft will be piloted at the proper height determined as in Rule of the Air (1) until it reaches a point immediately above the centre of the aerodrome. It will then be turned to port through an angle of 90° with its former bearing and will maintain a height during descent of 2,900ft. + the magnetic bearing of its compass course in degrees multiplied by ten and expressed as feet (*i.e.*, the magnetic bearing in degrees will be the height in feet less 2,900 and divided by ten). When, however, the turn has been made from the N.E. to the N.W. quadrant the height will be 100ft. for every 10° North of West + 2,000ft. Descending circuits will be left-handed." [5]

This " Descent Spiral " is 900ft. (90° × 10) vertically apart from the " Traffic Spiral," throughout the whole of the distance from 5,600ft. to 2,000ft., and there is thus considerable latitude for error. The pilot's compass can be up to 90° in error without even a possibility of collision with aircraft of the " Traffic Spiral."

Appendix " C " is a pictorial illustration of the Traffic and Descent Spirals viewed from above, showing the path of an aeroplane, on an original course of 360°N. and the path it would follow while in the Descent Spiral. It should be noted that aircraft following the Descent Spiral from different original courses cannot possibly follow the same path in the spiral. Their distance from the centre will vary according to the height at which they entered the spiral. There is thus a minimum of danger from other aircraft during descent.

It would be rather much to expect a pilot to work out his correct height from his bearing during a rapid descent, but cards could very easily be printed showing

[5] NOTE.—This is not optional, but consequential on the Rule.

the correct height for, say, every 20° of the compass and vice-versa.[6] It is unnecessary that a pilot should alter height during descent for every degree change of bearing.

4 Safety at Aerodromes (Ascents)

It will be noticed that no special spiral path has been reserved for ascending aircraft. This is, however, available at 90° from the Traffic Spiral in a direction opposite from that of the Descent Spiral or at 180° from the Descent Spiral. The reason it is omitted is that until rates of climb are at least double what they are at present the pilots will have ample time both for the simple calculation required in Rule (1) and for observation when altering his course.

Suggested Rule of the Air (4)

The following rule is desirable to ensure that aircraft enter the Traffic Zone and Spiral at the correct place :—

> "Ascending aircraft will enter the Traffic Spiral in a northerly direction at 2,000ft. (indicated) and will perform a right-hand circuit[7] until on the desired course. The height throughout will be determined as in Rule of the Air (1)."

5 Lighter-than-Air Craft.

No attempt has been made in this investigation to consider lighter-than-air craft. The heights available to them, and their bulk, ensure their safety. If desired, their aerodromes could be within scheduled areas prohibited to other aircraft to enable them to reach the upper zones by vertical ascent.

6 Summary

In conclusion I would say that of the four rules I consider the first to be of the greatest importance. The rule is simple to learn and easily applied.[8] The second and third are perhaps somewhat visionary ; nevertheless, I believe them to be the only solution of the problem of three-dimensional traffic over an aerodrome, and if applied now will but prepare pilots for times of greater air activity. The explanation of their necessity is necessarily somewhat involved, but their application[8] is considerably more simple than that of the multitudinous rules now in force to meet dangers which need never arise. The fourth rule is suggested purely for the guidance of pilots. Actually, it is consequential on the first rule, and as such is unnecessary except as a reminder.

Two objections are probable ; (1) the lost economy of time and petrol by not utilising favourable winds ; (2) the objection of the war-time scout pilot to whom the "freedom of the air" is still, as to most pilots, the greatest charm of flying.

To meet the first objection one has but to weigh the cost of the pilots' lives, the loss of equipment and passenger traffic against the value of a very small quantity of petrol saved, and to remember that, as previously shown, the economy is not entirely lost by aircraft departing to scheduled times. To the second objection one can but remark that there still remains an enormous space available for three-dimensional flying above and below the Traffic Zone.

It might be argued that the Traffic Zone, the Traffic Spiral and the Descent Spiral would interfere too greatly with the air activities of aircraft belonging to Flying Training Schools and Experimental Establishments. These places are, however, nothing more than the nurseries of pilots and aircraft destined for cross-country flying, and as such their requirements should be subordinate to the requirements (and safety) of aircraft all over the world.

If necessary they can be replaced within small scheduled areas over which the Traffic Zone regulations are not in force.

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[6] This is not optional, but consequential on Rule (1).
[7] See Appendix "D."
[8] See Appendix "D."

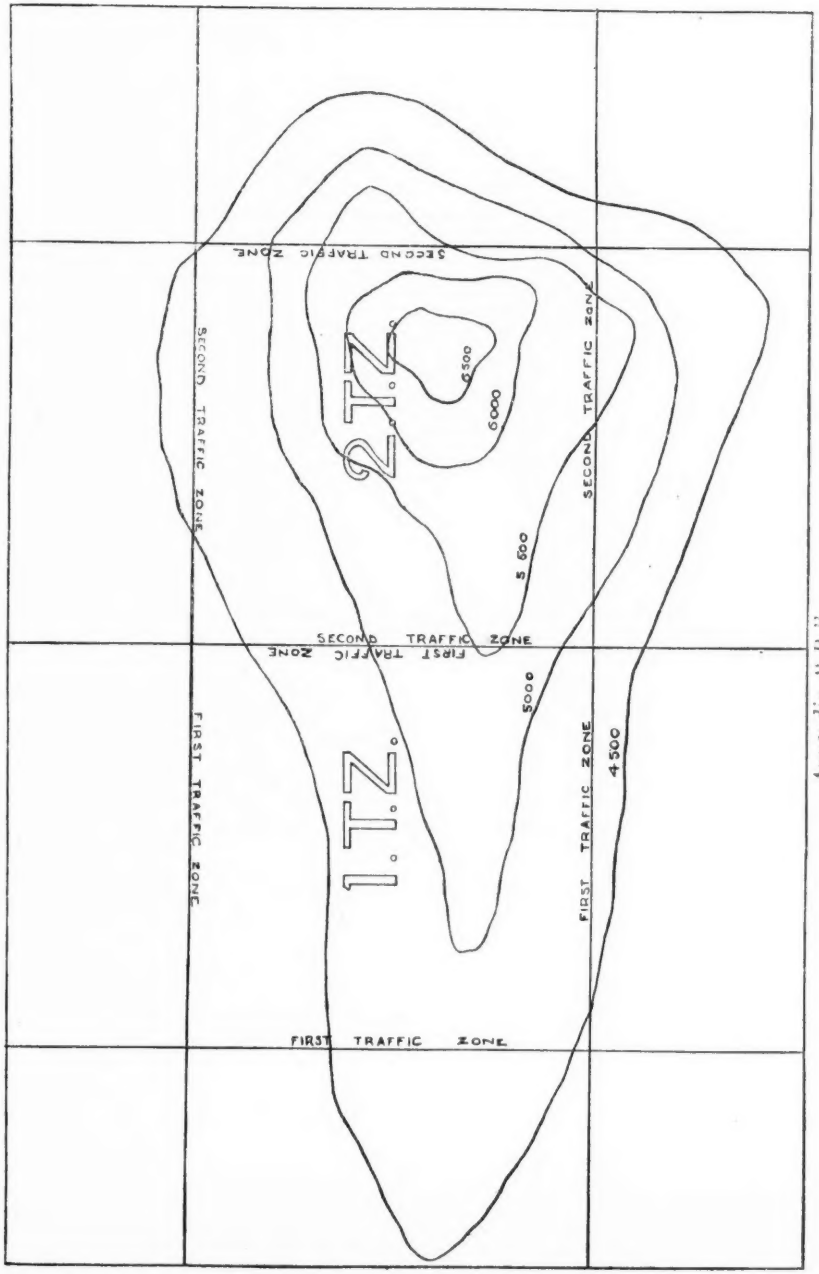
APPENDIX "A."

TRAFFIC ZONE INFORMATION.

RECOMMENDED TIME OF DEPARTURE (FOR AVERAGE CONDITIONS).

Magnetic Bearing of Course from this Aerodrome.	Jan. Best (G.M.T.)	Feb. Mar. Alternative. (G.M.T.)	April. Best (G.M.T.)	May. June. Alternative. (G.M.T.)	July. Best (G.M.T.)	Aug. Sept. Alternative. (G.M.T.)	Oct. Best (G.M.T.)	Nov. Dec. Alternative. (G.M.T.)
N. 0°	10.30	06.15	10.10	06.00	10.00	06.40	11.00	05.00
360°	11.45	15.10	11.30	16.36	12.05	13.01	16.15	06.17
5°								
6° 5′ (Croydon)	09.15	12.30	09.10	12.15	09.06	12.11	08.56	12.09
10°	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.
15°	,,	,,	,,	,,	,,	,,	,,	,,
20°	,,	,,	,,	,,	,,	,,	,,	,,
25°	,,	,,	,,	,,	,,	,,	,,	,,
27° 15′ (Biggin Hill)	,,	,,	,,	,,	,,	,,	,,	,,
30°	,,	,,	,,	,,	,,	,,	,,	,,
35°	,,	,,	,,	,,	,,	,,	,,	,,
37° 2′ (Kenley)	,,	,,	,,	,,	,,	,,	,,	,,
40°	,,	,,	,,	,,	,,	,,	,,	,,
N.E. 45°	,,	,,	,,	,,	,,	,,	,,	,,
etc.								

N.B.—(1) All figures above have been chosen at random.
(2) Different division of the calendar would probably be desirable.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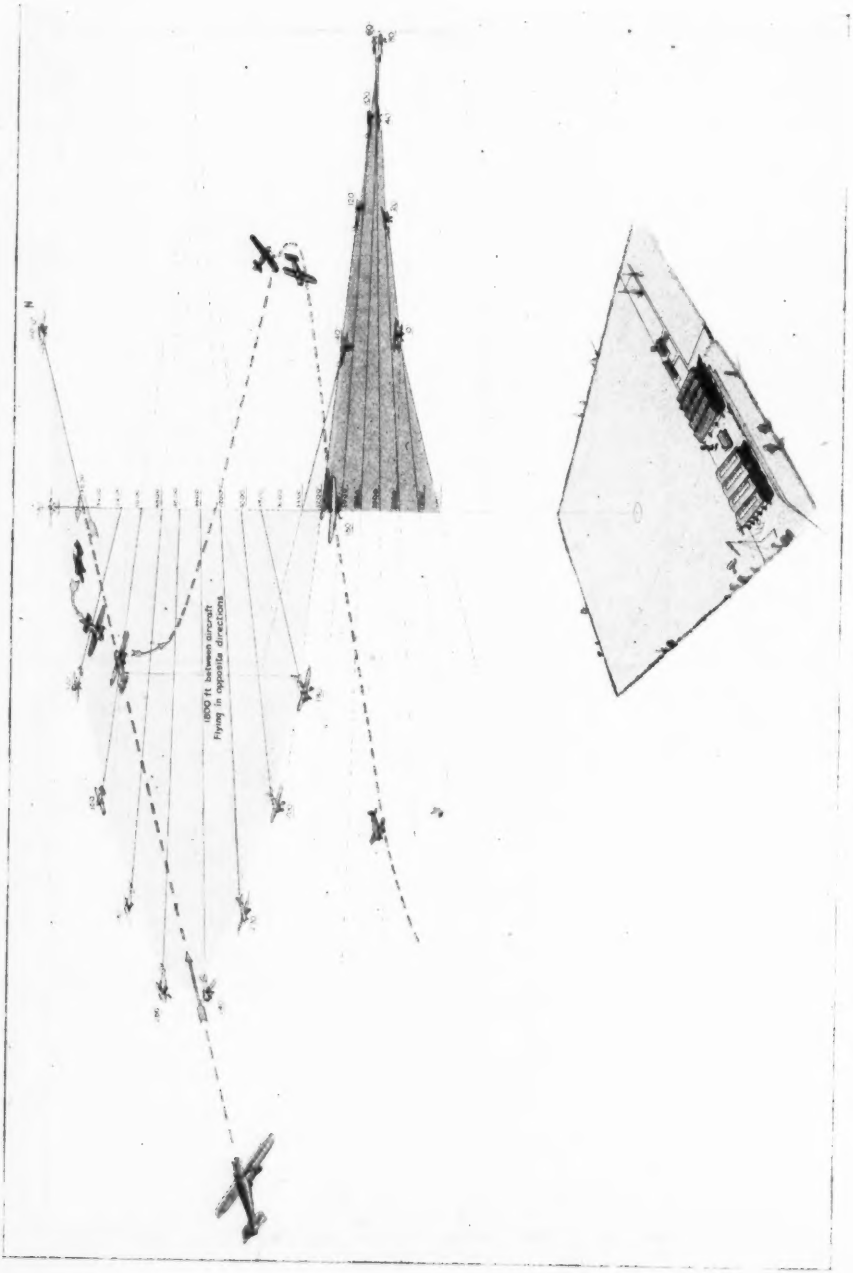
Appendix "B."



Appendix "C."

APPENDIX "D"

SPECIMEN CARD FOR PILOT'S COCKPITS.

HEIGHT IN FEET.

Compass bearing.		Descents* (at aerodromes only).	Straight course† or ascent or descent away from aerodrome.
N.	0°	2,900	2,000 or 5,000
	20°	3,100	2,200
	40°	3,300	2,400
	60°	3,500	2,600
E.	80°	3,700	2,800
	100°	3,900	3,000
	120°	4,100	3,200
	140°	4,300	3,400
	160°	4,500	3,600
S.	180°	4,700	3,800
	200°	4,900	4,000
	220°	5,100	4,200
	240°	5,300	4,400
W.	260°	5,500	4,600
	280°	2,100	4,800
	300°	2,300	5,000
	320°	2,500	5,200
	340°	2,700	5,400

* Keep on original bearing until over centre of aerodrome, then turn through 90° to port.
† Pass directly over the centre of an aerodrome or avoid it by (?) two miles.
Set your altimeter to your height above sea-level before leaving the ground.

NOTE.—(1) The above specimen card contains the whole of the instructions to pilots necessary to bring the proposed traffic zone regulations into force.

(Lectures on the principles underlying the regulations would however be desirable.)

(2) It is questionable whether the right-hand column of the card is required. Tests have been made over 15 calculations, and these showed that an average time of $2\frac{1}{5}$ seconds only were required to obtain the answer (*i.e.*, bearing $\times 10 - 2{,}000$). For the descent calculations, the average was $5\frac{1}{5}$ seconds, with a maximum of 11 seconds.

(3) 20° bearing is equivalent to 200 feet. This is the lowest division on the usual altimeter scale. The divisions of the compass have therefore been chosen accordingly.

AERONAUTICS

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Introduction

Since the various nations definitely set out upon the course of aeronautical armaments, the problem of the organisation of this new service has arisen, and appears to present serious difficulties if it should be necessary to effect periodical changes and modifications or at least substitutions in personnel.

This uncertainty is due partly to the fact that quite new questions are being dealt with; partly to the erroneous process of enforcing upon the new fighting service the rules of the older ones—the army and navy; and in a larger measure to the practical difficulties which have to be faced at every turn in passing from the theoretical field to the actual.

In the following pages an attempt is made to present the chief problems which arise in the aeronautical field, so as to form an idea for their solution, adducing opinions frequently diverse and antagonistic which the experts maintain in their respective arguments.

I SOME GENERAL QUESTIONS

1 *Problems of Aircraft Design*

The construction of aeronautical matériel presents peculiar problems because aircraft design is the most difficult of all among self-moving crafts.

Placed in order, according to their respective difficulty of construction, are:—The locomotive, motor car, ship, airship, aeroplane, seaplane.

In speaking of aircraft, the structure of the machine as well as the engine is included. The solution of the aircraft problem must be a reasonable compromise among a multiplicity of elements, *e.g.*, total weight, load, speed, power and dimensions.

That aircraft are the most difficult self-moved craft to design is shown by the fact that such was only accomplished when the weight of the motor was reduced to less than 6 lbs. per h.p. Again, the chief characteristics of flying are in conflict with one another. Climbing power and horizontal speed, climbing power and useful load, and for slower machines speed and useful load.

The landing speed must not exceed a certain figure or landing would be rendered too dangerous.

The strains and stresses upon the structure of an aircraft are infinitely variable according to condition of flight. In certain cases they may exceed three or four times or more those in normal flight. This renders it essential to give greater strength to the structure, while at the same time it is necessary to reduce weight to the minimum.

Whereas the weight of the engine must be reduced to a lower figure than in any other power plant, a much larger margin of reliability is required of it, as every stoppage of the engine means a forced landing.

2 *The Law of Power and Weight*

The aeronautical engineer has not only to solve the problem of the weight of the craft and of the engines; he is also faced with a mechanical law by which

the power of the aeroplane increases approximately in proportion to its weight; whereas in a ship or a dirigible engine power is increased at the index of two-thirds only of the weight, under equivalent conditions. Thus, while in a ship there is great advantage in increasing the displacement, for by that means the relative useful load increases while the speed remains constant, yet in an aeroplane the reverse is the case, and an increase of total weight progressively diminishes the relative useful load, so that it is impossible to exceed with this kind of machine a certain fixed limit of weight.

This explains why, after several fruitless attempts, the designs of the largest aeroplanes have been abandoned, these being relegated to a more advanced age.

This rigid law has, in fact, to be recognised and can only be overcome by increasing the efficiency of the machine and engine and lessening their empty weight by the use of stronger material. While it is possible that in the future machines will be flown of 100 tons or more, yet the present practical limit must be regarded as being from 15 to 30 tons.

3 *Theory and Practice*

The construction of aircraft has called for the greatest technical efforts, which have only been possible by reason of the high stage of perfection reached by mechanical science in general and by the application of innumerable experts to aeronautical researches.

The problem of flight to-day possesses fewer unknown facts than those of other older questions, as for instance the propulsion of ships. Aerodynamic laboratories fitted with wind tunnels for experiments with scale models have proved a most useful contribution. Aircraft designs which at first were arrived at by empirical methods are to-day based on scientific experiment, from which can be foreseen with great accuracy the result obtainable in full size machines.

We must, however, recognise that the first steps in aeronautics were due to the efforts of courageous men who, testing their own machines, established a starting point in the study of the new system of locomotion.

4 *Progress Accomplished*

The sum total of the studies, experiments and research in the laboratory and on full-scale craft accomplished in a few years, from 1908 till now, has been enormous, and has resulted in an amount of progress which otherwise would have required many years to realise, as has occurred in other fields.

On the one hand study has been directed towards the realisation of the greatest efficiency both in the wings and body as well as in the power plant. On the other hand, research has been directed towards producing materials and structures of greater strength in relation to weight. The results have been eminently satisfactory.

In aviation such materials are utilised as extra light alloys, steels of the highest resistance and plywoods which for their weight possess a much greater strength than the material employed in other mechanical constructions.

The progress of aircraft is apparent when one thinks of Wright's 25 h.p. machine compared with the 2,400 h.p. Atlanta; and of the speed of 54 km. per hour of the first machine to that of 450 km. of the latest; and of the total weight of 400 kg. to that of 15,000 kg. for aeroplanes and 140,000 for dirigibles.

Such progress is very gratifying when contrasted with that accomplished in the technics of other auto-motive inventions.

Railways, first commenced in 1825, have gradually developed up to the present day without making very wonderful strides. The speed has risen from 25 km. per hour to a maximum of 100, the weight of the trains and their equipment having increased proportionately.

The progress in naval construction has been relatively slow in spite of radical improvements in the driving machinery, which has passed from alternative engines to steam turbines and from the latter to the Diesel motors, the displacement of ships having grown from some hundreds of tons to 60,000; the power of 300 or 400 h.p. up to 180,000; the speed from 7-8 knots up to 35-40 as a maximum. Notable improvements certainly, but only attained over a long period. This is due to the fact that the locomotive and the ship of to-day are built according to the same main principles as those of a century ago.

Similarly, such progress in aeronautical practice, as can be attained by the application of already known principles, can only be very slow, being dependent upon the evolution of materials. We must emphasise the words " by the application of already known principles " because it is evident that the application of new ideas would result in a much more rapid progress in aeronautics.

Now, whilst noting with satisfaction what has been accomplished, it must however be admitted that theoretical conceptions have not been subject to any important changes since the first machines were constructed in 1907 up to the present day. Even to-day the aeroplane consists of a main lifting surface assisted by auxiliary control planes which allow the pilot to balance the craft and perform certain evolutions at will. What is commonly called aeronautical progress is perhaps merely the increase of these performances which depend directly upon the engine power, viz., horizontal speed, climb and load.

As regards safety, this is now enhanced by a fuller knowledge of the stresses of structures and of its behaviour in flight, but not much has been done to avoid or even reduce accidents due to the inherent nature of aeroplanes, owing to the fact that any functional damage, even to the unimportant parts, causes the pilot to make a forced landing, often with serious consequences. The question of safety is very much more important than it appears to be at first sight.

If aviation has not been developed as yet to a degree that might have been expected, given its advantages in relation to other means of locomotion, it is owing entirely to the lesser amount of confidence which the public has in that direction. We cannot attribute this to the fact that aviation is more novel, for even the motor car is new, and yet it has grown with remarkable rapidity. Nor are the accidents of such absolute magnitude as to influence the public, for aviation is directly responsible for only a negligible number of fatalities, but it is above all on account of their relative value.

5 *Air Accidents and Accidents in Other Means of Transport*

Comparing air accidents with those due to other means of transport, we find as a matter of fact a percentage greater in the case of the former. To say that air transport has now attained to the safety of other methods is an incorrect statement.

It is sufficient to compare air transport with that by motor vehicles, railway and ships. Last year in the United States for ten million motor cars there were 15,000 deaths. Allowing for every motor vehicle 450 hours running per year, carrying two persons, there is a death every 300,000 hours or one for every 600,000 passengers. It is to be noted that most of the killed are pedestrians.

An English railway company during last year carried over 40 million persons without a single fatality. A motor bus company carried 600 million passengers with 10 deaths, that is, one death in 60 million passengers. The figure for maritime transport is difficult to give as there are no exact statistics, but counting all transport services utilising water craft, there is not one death in 300,000 passengers.

In a continental commercial air service from 1921 to 1926 there has been one death per one thousand passengers; in another, on the contrary, there was only one death per 55,000 passengers.

Fatality statistics of the different air services show great variation as between one nation and another; although correct data are not available, figures can be quoted from the Press which show that the yearly death toll varies from 3·5 to 7 per cent. of the Pilots' Corps, each death corresponding to from 1,000 to 3,000 hours of flying.

It will be seen that air transport is relatively more dangerous than by rail, motor or ship, but the number of deaths relative to hours of flying show a distinct tendency to decrease, whilst the latter is increasing.

A further diminution in the number of flying accidents is to be obtained in three ways: By better instruction of personnel on the ground and in the air, by the adoption of safety measures such as fire extinguishers and parachutes and by improvements in the machines.

6 *Improvements to be Effected*

Excluding the discovery of new principles, as for example the De La Cierva Autogyro and the reaction propulsion or super aviation of Colonel Crocco, and on the assumption that evolution will be accomplished from that which already exists, we can predict that endeavours will be directed towards:—

1. Attaining a much higher speed than the present, which is too limited, by flying at the highest altitude.
2. Increasing as far as possible the weight of the machine, without of course ever exceeding certain limits, for the reasons already stated.
3. Ensuring a much wider margin of safety by means of the following improvements:—
   - (*a*) Automatic stability in flight, so that the machine cannot behave in such a manner as to endanger its control; or slotted wings and ailerons, so that machines be under proper control when stalled.
   - (*b*) Landing and taking off at a much lower speed than at present.
   - (*c*) Use of fuel safer than petrol.
   - (*d*) Floating devices for sea-going machines.

When the above improvements are effected a great number of flying accidents will be eliminated.

The adoption of the parachute as a standard equipment will result in a notable reduction of the losses arising from structural and engine failures in flight. It may be considered that even at the present time many fatal accidents would have resulted in the destruction of the machine and the saving of the pilots, if they had always carried parachutes. The flying authorities in the United States and England have made the parachute compulsory.

There need be no radical alteration in the design of aeroplanes or dirigibles, but it is possible that use may be made of lighter and stronger materials which may lead to a system of construction on rather different lines from the present.

As regards efficiency, it would seem that no very great improvements can be expected, unless new principles are evolved.

What has been said in regard to the aeroplane applies equally to the engine. The internal combustion engine has already a much greater efficiency than that of steam power. It will be possible eventually to still further improve this efficiency which is of the order of 24-27 per cent., but even if it were possible to raise it, it will be evident that the engine weight could not be made much lower. Consequently even in the case of engines, if there are no discoveries of new principles, nothing revolutionary can be expected, but merely a slow evolution.

If aviation has not yet reached such a comparatively high mark of perfection as to permit of its extensive application to ordinary use, it constitutes henceforth an important factor which everyone considers essential to the defence of the country. Hence the necessity for every modern nation to organise an air service

equipped with the best matériel and with a highly efficient personnel, utilising to the full those financial means which the economic conditions of the country will allow of being devoted to this branch of national defence.

Aeronautical problems include therefore the production of matériel, the training of personnel, and the military and civil organisation.

II. The Personnel

Usually, when speaking of personnel in aviation, we refer essentially to the pilots; but to deal fully with this question, we must also include the so-called specialists, on board and on ground, whose duties are of the highest importance, and the technical staff who superintend the production of the matériel.

The Air Service, even more than the Navy, requires of its staff special aptitude, necessitating a much more rigorous selection, for it demands technical, physiological and psychological characteristics which are not necessary in other services.

1 *Pilot Staff*

The recruiting and instruction of the pilots constitute one of the most difficult problems to be faced in the study of aeronautical organisation because of the necessity of

(i) The most careful selection of the personnel,
(ii) The difficulty of instruction,
(iii) The variably limited duration of the pilots' effective service.

(i) The selection of pilots is made upon international lines, which may also constitute a fundamental error; in fact the conditions should be adapted to the nationality and individual temperament. It is impossible to apply to an Italian the same conditions as to an Englishman. There are two essential points of view as to the qualities necessary in a pilot. Some consider that a pilot should possess only those physical attributes required in flying, relying for the performance of other duties upon any commanding officer who happens to be on board and who may not himself be a pilot. It would mean therefore that the position of a pilot would be reduced merely to that of a driver of the machine. The comparison of a pilot with a chauffeur, with a ship's steersman and with a locomotive driver, frequently occurs in discussions upon this point, though it does not at all represent the fact. Others consider that the pilot should combine in himself all the duties to be carried out on board and thus possess the necessary education.

By the first means the field of choice of the staff becomes enlarged and extended to categories of persons of whom there is an abundance. By the second, however, the choice is narrowed to those classes who, sometimes, are not the most likely to exhibit the necessary physical qualifications.

The question of psycho-physiological fitness is thus of prime importance. The objection has already been made that not all the nations would be able to adopt the same standards for the selection of pilots, but that the general rules should be adapted to the different races. This is undoubtedly true, as the normal Italian, or African, or Englishman represents in himself an entirely different type, while being quite normal to his respective race.

To demand from the general body of Italian pilots the same conditions as are required of English pilots means reducing enormously the field from which our pilots can be chosen. At the time when rigorous examinations were not yet in force, men were passed for pilots who exhibited in practice complete efficiency and who, on subsequent medical examination, proved unsuitable.

(ii) The pilot's training should confer upon him not only the necessary knowledge for flying a machine, but also that required for war service. The latter is as essential as the former.

Flying a machine under normal conditions does not present any special difficulty, and any ordinary person can learn it in a very short time. But it would be a serious mistake to limit a pilot's instruction to merely flying under normal conditions. This would give rise to many more accidents than those occurring at present.

The possible and varied damages which may be sustained by the machine presents the pilot with many problems which must be instantly answered, and only long experience will enable him to do so.

Generally speaking, the difficulties occur in taking off, in landing under abnormal weather conditions and in forced landings. The fatigue caused in normal flying is almost nil, in fact the pilot experiences quite a pleasurable sensation.

The instruction of pilots is a costly matter in two ways, because it requires many hours of actual flying, and because it may cause serious losses both in matériel and of human life. Generally, however, it is much better and more economical to give longer courses of instruction in the schools, so that the pilots are sent to their squadrons with a perfect technical knowledge of flying, for thus, in their subsequent service, they avoid the more costly accidents due to incomplete instruction.

Training may be carried out in government schools where the instructors are officers; or in private schools, where a certain inclusive fee is paid for each licensed pupil.

In some military air forces the prevailing principle is to consider the pilot's ability when flying alone. A pilot is classed highest who can carry out evolutions and aerobatics, fly in any kind of weather, land in restricted spaces, and land with the least damage in case of engine failure. In other cases, while placing a certain value on the latter, the greatest importance is assigned to a pilot's ability in formation flying. Pilots are accustomed from the commencement to flying in formation, first in sections, then in squadrons and finally in groups.

In the same aerodrome two or more groups carry out simultaneously taking off and landing manœuvres. Such combined instruction is regarded as absolutely essential, as future aerial warfare is expected by experts to consist not only of a series of individual duels between fighting machines, or between fighters and scouts or bombers, but as a mass action, in which ability to carry out combined manœuvres will be the principal factor affecting the result of the conflict.

The characteristics of the machine therefore tend to lose much of their relative value. Between two bodies of machines of the same power, superiority will lie with the group whose pilots are the best in performing combined evolutions, for the differences which exist to-day in the climbing power and speed of two machines fitted with similar engines, or with engines of equal power, are very small.

On the contrary, in certain air forces there prevails the tendency to assess these qualities and these small differences at an abnormal value. An extra fraction of a second taken in a climb is sufficient to cause one machine to be regarded as inferior to another, and to discard it, often entailing a considerable expense in changing the type as well as involving all the other practical inconveniences which a change of type imposes.

The objectors to this system maintain that assuming combined manœuvres are of prime importance in aerial tactics, and also that such manœuvres can be carried out and learnt with machines not possessing the highest qualities, it will be seen that it would be wrong to judge an air service on the basis of performances only, and in any case it would not be possible to attribute the supremacy of an air force simply to the fact that some of its machines are slightly better.

The instruction of personnel may be considerably stimulated by competitions between the various units of the different classes of machines. Some air forces give an annual public display of the ability of their personnel and the soundness

of their matériel by means of ground exhibitions of the machines, formation flying, speed races, bombardments and ground attacks.

Others prefer to assert themselves by undertaking long inter-continental journeys, specialising either in long flights without stop, or stopping along the most varied and difficult routes.

Long flights take the place of the long sea voyages which between the 15th and the 18th centuries made the great navigators famous. They have the advantage of making general aeronautical propaganda and particularly for the benefit of the industry and the people of the country concerned. They magnify therefore the prestige of a nation and strengthen the bonds of the mother-country with those belonging to it who live abroad and take pride in the passage of the aeroplanes.

At other times these flights are of a scientific discovery character. These are nearly always financed by the State and sometimes assisted by the industry directly interested.

Together with these advantages there are, however, considerable inconveniences which have caused some nations to at least abandon individual long flights, substituting them with others made in groups. Individual flights may constitute in fact a bone of contention amongst pilots by reason of the reward accorded to the one who performs them. The best members lose interest in the ordinary service and tend to dedicate themselves to anything that might bring them into prominence.

The cost of these flights is great and the amounts which are spent upon them, declare the objectors, could be utilised to better advantage in scientific research and experiment.

What then if record flights are made with foreign matériel? The main object of national industry propaganda fails, so that the objectors consider it would be advisable that flights should be made with groups of machines and with national matériel.

(iii) The duration of a pilot's actual and effective service varies and depends not only on the individual himself, but also upon the circumstances affecting his life as a pilot.

A pilot's fatigue is primarily due to accidents which he cannot avoid and which adversely affect his morale by the fact that he no longer feels safe in facing particularly dangerous conditions. There comes a moment in which the pilot loses faith in his machine and in himself. At this point it is necessary that the pilot should temporarily give up flying.

Fifty per cent., if not more, of fatal flying accidents are reported as being due to error of judgment on the part of the pilot, and we may be sure that these mistakes occur with pilots who have reached the critical point of their physical and mental equilibrium.

Every accident generally means a reduction in the time of possible service. It is impossible to quote definite figures, for some pilots are exhausted after two or three years' flying; others are still in good condition after ten or fifteen years or more.

It is certain, however, that at least the present period of effective service of an officer pilot is very short. Hence the great difficulty in forming a permanent corps of officer pilots, for after a few years they are no longer fit for flying duty without exposing themselves to serious risks. And consequently the various nations are seeking a solution to the problem.

In England the Corps of Flying Officers is amalgamated with that of the technical ones, which thus permits a certain portion of the flying officers, who have the capability and the knowledge, to pass to the technical services without abandoning their career. Further, the Air Force is composed partly of permanent officers and partly of temporary who serve for five years, after which they return to civil life. And as not even this would suffice to provide the

necessary number of pilots, they are supplemented by non-commissioned officers and men.

In the United States and in France, the Air Services not being separated from the Aarm and Navy, officers no more fit for flying can return to the service whence they came.

2 *Aircraftsmen and Air Mechanics—Ground and Flying Sections*

The skilled men's duty is the maintenance of engines and aircraft, their minor repairs, the use of armament, wireless and photographic apparatus.

The instruction of skilled craftsmen and mechanics presents less than that of pilots, but still considerable difficulties. The employment of motor mechanics, wireless operators and gunners, who have a full knowledge of their matériel which allows them to use it in the most effective way, is of prime importance to the service.

Unfortunately, if not neglected, the instruction of such men is generally regarded as secondary to the pilots' and is considered as supplementary. This is a serious mistake.

The consideration of the causes of accidents which occur in flying suffices to show that over two-thirds are due to damage of a minor nature, which even so causes a forced landing.

The instruction of skilled craftsmen requires complete courses of theory and practice over an adequate period. The opinion that it is possible in a few months to train a motor mechanic, or a wireless operator, signifies that one has no correct idea of what constitutes the basis of aeronautics.

While in any other means of transport the knowledge of technical details is not of essential importance, in an aircraft there can be no graduation in importance, for damage even to a non-vital part may compel the pilot to land. For instance, the essential parts of the engine may be in perfect order, but engine stoppage may be caused by the least fault in the ignition circuit. An obstruction in an oil pipe due to careless cleaning, may set up overheating and cause a failure, and so on.

In wireless it is a proved fact that with the same set the best communication may be obtained, or—on the other hand—nothing at all. It all depends upon the operator's ability.

The use of a sighting instrument for bombing requires the most scrupulous instruction both on the ground and in flight. Even the use of a camera also calls for long experience.

Seeing that military aircraft are built for a definite warlike purpose, either for taking photographs, or sending wireless messages, or bombing, it is evident that if the staff be not efficiently trained, the machine itself becomes useless.

3 *Technical Personnel and Flying Corps*

The technical personnel are those civil and military who are concerned with the design and construction of the machines, and the inspection of the constructing companies or firms. The aero technical staff must be trained in flying. They must possess the general education which is required of an engineer of whatever civil category, whether industrial, mechanical, naval or chemical, and in addition they must have specialised knowledge of aeronautical science.

If the technical personnel be trained in flying, they will regard the problems of aero construction from a different angle to a staff who do not participate in the risks of flying, but conduct all its researches in the laboratory.

The technical corps must be trained especially in the testing and inspection of the material. For this, all engineer officers should possess a pilot's licence and should take part in test flights whenever possible.

It is absurd that the technical corps should be restricted to workshop duties only. They must have full knowledge of the piloting of aircraft. Only in this way can they give to the air service their most valuable assistance. This idea is carried out in the only two independent Air Forces in existence—the British and the Italian.

In the British Air Force a certain number of pilots, who have aptitude, are singled out and sent to the engineering schools for the completion of their technical instruction, after which they pass into service as technical officers. In Italy instead, young engineer officers are enlisted and sent to pilot schools as candidates for their flying certificate, afterwards serving in a separate corps of the Air Force, the Aero Engineers Corps.

Compelling the technical personnel to undertake flying will greatly reduce, if not extinguish, the antagonism between themselves and pilots, which has always had such a deleterious effect upon the service and the progress of aeronautics generally.

There has always been amongst pilots generally a certain innate hostility towards the so-called table experts, that is to say, those who, while remaining on the ground, assume responsibility in the building of the machines. It must be realised that in the past there was some excuse for this hostility, for it has often happened that pilots have been given machines to fly upon which the builder himself had not any trust. The function of the aeronautical engineer ought to be quite otherwise, and this is by no means impossible because he may have all the knowledge of the science of construction, and at the same time possess the physique adapted to flying.

The antagonism between the two classes can be explained by the fact that they speak two different languages and are unable to understand one another.

The constructor, who remains on terra firma, is inclined to overlook, as of secondary importance, all those details of equipment which render the working of the machine easier and safer in flight. Did they fly, they would bear in mind that it is not enough to give an aeroplane an efficient shape and a good aerofoil, but it is to be remembered also that there is a human being living on board, if only for a few hours at a time.

Above all let us refer to the lay out of the wireless instruments, the camera, the guns and the bomb releases, to which so much study has been given, but which often compel the pilot or observer to make awkward and tiring movements.

Another problem of great importance is that of increasing the pilot's chances of escape under all circumstances.

The aeronautical engineer to-day usually acquires a good all round education in general aerodynamics, but this is not sufficient, and especially for a military engineer, it is essential that he should have a thorough knowledge of the equipment of machines. Something has already been accomplished in this direction, but much still remains to be done.

Until recently constructors and technicians in drawing up the design of a military machine concerned themselves primarily with its flying qualities and performances and only secondarily with the question of its equipment. Now it is well to state, as a basis of military aero construction, that the value of a military machine depends on how far its equipment fulfils the purpose for which the craft is intended.

A scouting or observation machine which has not the necessary space for wireless apparatus or camera, and does not offer the observer the necessary accommodation for their operation, is completely useless even if it has the highest performance. The same may be said of a fighting machine in which the machine guns are badly placed, or in an awkward position for the pilot; and of a bomber which has not a reliable arrangement for bomb dropping.

It is necessary for the technical staff to have a thorough knowledge of these points, if they are to give the builders the necessary directions. To leave these

matters to the builders and to limit oneself to rearrange, if necessary, the equipment by the aid of the pilots, only leads to loss of time and money.

Some consider that the equipment arrangement should be studied only by pilots, namely, by the users of the machines. There is no doubt that there are pilots who have the knowledge and aptitude for such work, but in this case they are no longer pilots only, but technical pilots and as such they come within that technical category which is so much desired by aviation experts.

Instead of asking the opinion of a pilot upon a machine already built, it would be better to have his ideas upon the design of the machine about to be built. Most pilots have not such a technical knowledge and familiarity with designs as to allow of their expressing an opinion from the examination of a mere drawing. In this case it is better to make, on economical lines, a model of the essential parts of the machine, a mock up as it is called in the shop, so that the builder and the pilot may both see for themselves the range of vision allowed and the various equipment arrangements. With very little expense one may in the end avoid very costly structural alterations.

This is the most reasonable and effective collaboration which can be desired between pilots and constructors.

Experimental construction is based essentially upon researches in the laboratory and in flight. Technical men who devote themselves to these two branches have the same professional education, but they apply it in different ways.

Aeronautics is one of those subjects in which, more than in other sciences, there has been the closest collaboration between engineers and scientists, and this explains the progress attained in the comparatively short period of time.

The need for this will never be sufficiently insisted upon and therefore the activities of the technicians, concerned with the two departments of research, could with great advantage be made alternating.

The technical aeronautical corps must be capable of fulfilling both functions, that is, they should be able to carry out scientific and practical researches in the laboratory and workshops and then be able to apply their results in practice. Only in this way the scientific problem will be regarded not as an end in itself, but rather as a means of realising an actual progress.

III. The Materiel

The production of the matériel includes the study of prototypes or experimental machines.

1 *Government and Private Industry*

In Italy naval and military construction was at one time entrusted exclusively to the State arsenals. It passed subsequently to private concerns to which it is to-day wholly assigned.

In England and in the United States, however, warships are built partly in the Government arsenals and partly by private industry.

It is generally objected that Government work is too costly. But this may be a pure fabrication originated and upheld by those industries who would not only belittle a redoubtable rival, but would above all nullify the possibility of the control upon practical grounds of the price of matériel.

When in fact the industry had no more fear of State competition, prices arose to very much higher figures than those of the State itself; to say nothing of the prices charged for repairs for which, owing to the difficulty of giving exact quotation, firms may impose exorbitant charges so as to protect themselves in case of error.

In spite of this danger we must recognise the convenience of leaving the work of production of aircraft to private industry. By checking and controlling prices and by taking advantage of the competition existing between the different

factories, a businesslike Government administration can always obtain fair quotations.

As regards experimental work, or work connected with experimental machines, this should be entrusted partly to the contractors and partly to Government establishments. By this means the technical director of the department concerned secures not only a most valuable knowledge of the methods of construction, but may contribute effectively to the progress of aeronautics and also, by his first hand knowledge of the subject, give a lead to the industries interested.

This competition in the field of experimental machines is not in the least prejudicial to the industry which generally undertakes this part of production unwillingly on account of its high cost and the uncertainty of its results.

After all it is for the Government to carry out either directly or in subsidised laboratories all those researches of a scientific nature which call for special plant and a technical and scientifically trained staff. As the development of technical education in aeronautics is of the highest importance, the Government should encourage the establishment of scientific laboratories attached to the engineering schools, which laboratories besides being useful for the required studies and researches, would also serve for the instruction of the pupils.

As a fitting complement to this system of institutes, it would appear advisable to establish a National Physical Laboratory on the same lines as the Bureau of Standards in the United States, the National Physical Laboratory in England and the Imperial Laboratory of Berlin.

2 *Selection of Types of Aircraft*

The characteristics of new machines should be the result of a compromise between the needs and views of the Air Staff and the technical possibilities. These characteristics should be imposed upon the manufacturers, who ought not to devote any special initiative in that matter. Actually, however, the strategy and tactics of aircraft being infinitely simpler than those of other instruments of war, it may be taken that they are also known to others unconnected with military air service, so that even the manufacturers themselves may often be in a position to suggest new types of aircraft.

For instance, in certain categories of machines improvements to be looked for are obvious. In a fighter we have to increase speed of climb and manœuvring efficiency, for scouts range of action, for observation machines range of vision and convenient equipment arrangements, for night bombers maximum load and range.

To allow the manufacturers to do so may possibly complicate the programme of aeronautical construction and render more difficult the industrial problem, to facilitate which it would be desirable that each contractor should specialise in only one or two types of aircraft. It is evident that if the same type be furnished by several firms it will necessitate much more complex work in deciding the choice. Further, a great part of the experimental work will have been done without any useful purpose, ill-feeling and jealousy will arise between the various firms and uneasiness among the pilots will be prolonged.

It is necessary to have a clear idea of the psychology of the pilots in order to understand the conditions prevailing in aviation, which are totally different from those of all other military spheres.

In the Air Force the pilot, whatever his rank, by the sole fact that he does equal duties in all ranks, claims to be similarly competent in judging the matériel.

In the Navy, officers of lower rank do not concern themselves with offering opinions regarding the chief units. But in the case of lesser units, viz., cruisers, destroyers, submarines, it is evident that the opinion of the commanders, although they be of lower rank, has the same weight as that of the commander of battleships. In the Navy, however, apart from the destroyers, the commanding officers have at least the rank of lieutenant-commander.

In the Air Force, pilots may be of all ranks, from private to colonel. Theoretically, therefore, the range of the experts includes all the flying personnel. Further, some aircraft, such as fighters, are single-seaters, so that if the heads of the service are not themselves pilots, they must submit to the opinion of their dependents. The question is thus different from that in the Navy where the qualities of a ship are easily ascertainable.

It is only natural that the opinion of such a complex body should be at variance, quite apart from any personal motive.

An aircraft is the most reasonable compromise between essential qualities sometimes diametrically opposed to one another. It can be appreciated therefore that it may be comparatively easy to criticise machines when only a few sides of the question are considered. To avoid the most serious consequences it is absolutely essential that the decision upon the selection of machines should be made personally by the responsible heads of the service.

A system of avoiding such a responsibility has been to entrust the decision to committees of pilots and technicians. This arrangement is still more prejudicial than that of leaving the decision to single individuals. As a matter of fact an unlimited number of committees could be appointed, resulting in an equally infinite number of different verdicts. In estimating a machine by a committee, it is practically impossible that they could distinguish between faults arising through a faulty drawing from those due to a bad execution of the design. It often happens that defects are attributed to a certain type which are in reality due to details in construction and to the material. Only the heads or principals can adjudicate with sound knowledge, taking into account the various opinions, and of course when they have a full experience of aerial navigation. Only in this case they will be able to consider all the fighting, technical and economic factors, which in the end give definite elements for judging.

3 *Assessment of the Results of Acceptance Tests*

The progress made by aeronautical science, it may be mentioned, now permits the valuation of the performances of a machine being taken from the trials of a model, and not only speed and climb can be judged, but also its manœuvring capabilities, the checking of the results of test flights always confirming those obtained in the wind tunnel. Every machine should be judged exclusively by actual results and not by estimates which have only an empiric basis.

The carrying out of acceptance tests of aircraft, and consequently also of aircraft of a new design, should be made under identical conditions for all of the same class and should be under the control of the same body. If the test pilot was the same for all aircraft there would be more certainty of a uniform judgment. This, however, is impossible for it would be unfair to debar the builders from getting the best out of their machines by employing their own pilots.

It is extraordinary how with the same machine and engine such varying results can be got in speed and climb on account of different weather conditions and more or less tuning up of engine and craft.

At one time the most amazing phenomena occurred in the test trials; the machine was even tried with different wings for speed and climb and with different propellers. An engine whose valves have been ground in and in which the compression and ignition advance have been altered can give a power increase of 20 to 30 per cent. and even up to 50 per cent. of its h.p. developed normally over a prolonged period of service. It will be seen, therefore, what discrepancies may appear in the performance of the first trial of an experimental machine and that which a production machine may show.

Another means of defying the first acceptance test is that of eliminating all those parts which may increase resistance, for example, radiator fins, guns and

supports, exhaust pipes, etc. It is endeavoured besides to reduce to the minimum the weight of fuel, particularly when the contract does not state the useful load, but only the number of hours of flight at high altitude. Often during trials the wheels were changed for others with smaller sized tyres. If the pilot knows the local atmospheric conditions he can make use of ascending currents which occur at certain hours of the day.

It will be seen, therefore, what a delicate matter it is to give a uniform opinion upon different machines, and how absolutely impossible it is to compare the acceptance tests of an experimental machine with the normal performance of a service machine.

4 *Difficulties in Attaining Rapid Progress in Materiel*

The choice and production of matériel presents the most serious difficulties in times of peace; it can be imagined what these difficulties are in time of war with the most rapid increase in air units.

While rapid progress should be aimed at in the qualities of aircraft, it may be that the personnel are unable to keep pace with the production of matériel. Aircraft more speedy and powerful are usually more difficult to pilot than those possessing less pretentious qualities, and while the Air Force asks for machines superior to those of the enemy, it may happen that their use is shown to be impossible.

During war the question of matériel is therefore more acute and may lead to serious crises owing to shortage of supplies for the front. Therefore there are some people who prefer to maintain supplies upon a basis of well tried and tested machines even if they have not the exceptional performances attributed to enemy machines.

Fortunately, with the advance of aeronautical science, the design of new machines no longer presents the difficulties encountered in the past, and it becomes therefore less likely that a new machine will not give the results anticipated in the design. Secondly, the improvement in matériel having followed an ascending course, now approaches the summit of the curve which indicates standardisation of engines and machines, or at least of certain parts.

This, however, must not satisfy constructors and crystallise types, which should still be subject to continued improvements.

One of the greatest difficulties of the aeronautical industry is to introduce new types and new materials for construction, and this, in different forms, has occurred in all fields—shipbuilding, railway construction, etc.

The evolution of the sailing ship to the steam power and of wood construction to iron was met by furious and implacable objectors, who swore that steamships would never be able to render efficient service and that iron construction would never be adopted in practice. This is mentioned in view of the arguments put forward to-day upon the adoption of metals for building aircraft.

Although the problem is not exactly identical with that of shipbuilding, it is as a matter of fact very similar, which is shown by the tendency, now pronounced, of taking aeronautical construction along the same essential lines as those of shipbuilding, whether for aircraft or for dirigibles.

In aeronautical subjects, more than in any other, prejudice must have no place, nor empty phrases or slogans; but the results of practical experience alone must be accepted, even if these are contrary to expectations and to theory.

Sometimes it is not enough to take account of the behaviour of a machine in flight only, it is necessary also to foresee the behaviour in case of forced landing so that the pilot may be afforded a certain degree of safety. Very often machines giving the best of performance and easy to control are regarded with aversion for war use precisely, because if brought down the arrangement of the crew would entail their almost certain destruction. It is therefore the builder's duty to ensure that in the eventuality of a turn over in a forced landing the

crew may have a reasonable protection by the most robust parts of the structure. It is a great mistake in military aviation to regard as of secondary importance the safety of the crew. Apart from humane reasons, the need of preserving young lives is obvious, they being the nation's most precious asset. The greatest attention should be given to this point, in order that flying accidents may be reduced to the minimum.

Frequently there is contradiction between purely aeronautical and fighting properties; for example, the disposition of three engines in a night bomber, one forward and two lateral, is best from the aeronautical point of view, but cannot be adopted because of the obstruction to frontal defence and so fails short for war purposes.

In an observation or scouting machine the range of vision and the means of defence are often in conflict with each other, though the machine's design may be quite reasonably good from the aeronautical standpoint. In the first case it should be arranged that the observer should not have in front of him anything that impedes his vision, whilst for good aerodynamic efficiency the fuselage type with tractor propeller has been resorted to. The same may be said of fighting machines, where the pilot ought to have an uninterrupted range of sight.

5 *Experimental and Production Machines*

It is a difficult matter to reconcile industrial exigencies and aspirations with economy and advantage to the State.

Every aeronautical industry endeavours generally to construct machines of its own type for moral reasons and material interest, as in such cases it may impose upon the State its own price for the machines as the State would have to place the order with the contractors without competition.

This tendency conduces to a superabundance of types and to a difficulty in making a wise selection of the required type. It leads to a rapid passing of matériel, which as a whole is contrary to the standardisation and permanence of the types which in practice possess great advantages for war service.

The creation of a new type of aircraft, from the instant when the design is commenced to the moment the completed machine enters its squadron on normal service, requires a much longer time than that which might be anticipated from the limited size of the craft.

The following details are confirmed in actual practice:—

Drawing up of the design	3	months
Model trials and experimental tests	1	,,
Building the first sample machine	10	,,
Flying tests, remedying apparent defects, tuning up of the machine	6	,,
Construction of developed machines	10	,,
Experimental squadron tests and alteration of equipment arrangements	6	,,
Mass production and first delivery to the squadrons	8	,,
Total	44	months

Of course this period can be cut down, but not much. One can indeed do without the experimental squadron, which consists usually of 10 to 12 machines, by making at first four to six machines instead of the single as sample. But this procedure exposes the Government to serious risks from the commencement, for, having set aside larger sums, they are not inclined to give up the type of machine although it gives not wholly satisfactory results.

In any case we are always dealing with a period of about three years from the moment of the machine's conception until entering actual service.

Generally the sample type, as already said, gives results much superior to those of the experimental squadron machines and also of the service machines, for the following reasons:—

Because its engine is specially tuned up; because frequently the first machine does not carry fittings or equipment which must subsequently be added in the course of testing; because specially favourable weather conditions are chosen for testing although the reduction of performances in standard air will considerably lessen this source of error; because the pilots employed are the best obtainable.

It sometimes happens that after a machine has passed the full ordeal of testing and is ready to enter in production or in normal service, another constructor, with the same type of engine slightly improved or with a new type of engine, will submit to the initial trials a new sample aircraft of the same class. It is evident that the trials of this last type would show better results than those of the experimental squadron machines, and so those who have to decide upon which to adopt will be greatly troubled and uncertain in the face of the new results which are enhanced to the utmost value by all means at the disposal of the constructor.

The reply in this case is very simple, for it is obvious that when the second type of machine itself passed the first tests and also those of the experimental squadron, it would not then exhibit the qualities claimed for it.

As it is a fact that dissimilar elements cannot be added up, so it is impossible to compare machines which are not at the same stage in their construction. It is not possible to compare the performance of a sample machine with that of a machine already in service.

However, despite the fact that this position repeats itself incessantly, it has not yet been possible to ensure once and for all the inviolability of this principle which, had it been observed in the past, would have prevented disappointments and serious losses, especially in war time.

In time of peace, in fact, everything is reduced to an economic loss more or less serious, while in time of war the additional danger is that of not having machines at the front in time.

It has in fact happened that the production of a machine in service which gave satisfactory results has been abandoned in favour of another machine whose performance was based only upon the sample submitted, while afterwards the whole series has had to be discontinued on account of certain short-comings, thus reaching a point of having neither the old nor the new one.

The preliminary study and design of machines is sometimes done independently and without full consideration of their intended use and of their equipment. Then when the machine is built expedients have to be resorted to for the arrangements of the various fittings, guns, instruments, etc., and sometimes the most important points have to be sacrificed because sufficient space has not been provided in the proper place.

It is possible also to err in the opposite way by building machines which, though they be the best in time of peace because they fulfil armament requirements, are yet deficient in performance as compared with those in use in other countries, so that their employment in war becomes practically impossible.

Before proceeding to the construction of a prototype, plans must be drawn to a 1/5 scale with full equipment arrangements and, as already said, also a mock up must be made of the fuselage with the central portion of the body and undercarriage so as to give the pilots a clear idea of the machine.

The assistance which pilots may give in designing a new machine is very great, especially in cases where the technical designers lack the necessary practical knowledge. Idle discussions must however be absolutely avoided and one or more equally efficient solutions must be submitted to the pilots, so that

they may make their choice while adhering to the essential points of good efficiency as regards aerodynamics and fighting qualities.

In the field of proposed designs there are many of these which do not correspond to present technical possibilities, but only to those of the future. Among the most common are:—

Mammoth machines of 50 tons or more, carrying 200 or more passengers.
Machines for flying at extreme altitude (60,000 ft.).
Fastest machines (400 to 600 miles per hour).
Engines of the greatest power (5,000 h.p. or over).
Extra light engines (¼lb. per h.p. or less) and so on.

These designs are often submitted by technical engineers in a theoretically correct form and frequently lead to very considerable expense in experimental work which yields a very small practical result.

In an institution such as a military air force in which the economical factor has a capital importance, it seems necessary to keep quite separate experimental activity from industrial production.

The aeronautical industry should be called upon to supply in the most economical way those machines which are needed by the service.

These aircraft, while on the one hand they shall represent the most advanced possible type, cannot on the other hand be changed too often either for economical or practical reasons. It has already been seen what a long period is required to produce a certain definite type of machine. It is evident that the duration of service of a certain type, especially in peace time, must not only correspond to the average life of the craft, but to a much longer period.

The advantages of retaining for a long time in service a certain type of machine are considerable; the crew and ground personnel acquire by that a great practical experience; the small residual defects are remedied; supplies are ensured with greater facility and economy; flying accidents are diminished and the general efficiency of the squadron is increased.

For these reasons it is recognised that every change of type should be accepted only by a marked inferiority of the ordinary machine in respect to a new experimental type. For if the characteristics and the performances are not much different, it is better not to interrupt supplies of the old type; it may then come about that the industry will submit new types of machines, and these may be successively approved and passed through the various stages which have been enumerated, and finally it might be found advisable not to change the type in service.

6 *Industrial Production*

The industrial question with regard to aeronautical construction is one of the most difficult to answer. Aircraft not only requires accurate construction with the best matériel, or rather, with *exceptional* matériel, to possess the necessary strength without exceeding the weight provided by the design, but they must also comply with those qualities of shape and proportion which are required for a high degree of efficiency.

In any aeronautical factory, therefore, are necessary an engineering staff capable of designing the machines, keeping up with the progress and a staff of skilled workmen who can execute and produce the machine as designed. The closest collaboration must be maintained between the drawing office and the workshop. When that does not occur, as it often happens, machines well designed do not give the expected results, either technical or economical.

It frequently happens that the designer of the machine concerns himself only with the plotting out of the dimensions and outline required for a predetermined result, regarding as of secondary importance the structural design of the aircraft.

Sometimes, in order to attain better results, the drawing office imposes constructive details very costly on account of the quality of material required and of the workmanship. This may prove harmful because, as already stated, the economic factor is of prime importance.

Another difficulty encountered by the aeronautical industry is that of obtaining sufficient work to carry on without interruption. The orders which the State may place with the firms are influenced, as well as by budgetary considerations, also by the policy which it is intended to follow in the renewal of material, or by the period during which the type of machine is renewed, by the duration of a certain type in service, by the life of the machine, by the number of types simultaneously in service.

The constructor generally prefers to receive orders for large batches, and this chiefly for moral reasons, because a large contract with the State nearly always raises the value of the shares of the firm and increases the amount of credit which it can obtain from the banks.

The price of an aircraft depends upon the number ordered and generally decreases with an increase in that number. While, however, there is a very great difference in the price in ordering one or ten machines of the same type, the difference is much less marked when ordering 100 or 1,000 machines.

The work of construction of aircraft is now in a large measure manual, especially if made in wood, therefore the production of aircraft cannot be regarded as similar to that of motor cars.

It is risky to order in too large quantities, especially if the contractor is not accustomed to large production, because as a much longer time must be allowed him for delivery, it can be found that during the first few months the work has not been organised with due rapidity and great delay is occasioned.

In peace time, therefore, it is better that the groups ordered should not be too large, so as not to have to set aside large sums from the Vote without the assurance that the goods will be delivered in due time. This difficulty of obtaining delivery from the contractors, once the contract is signed, is characteristic of the aeronautical industry. In no other, in fact, is the risk of non-fulfilment so great, and this not only with small firms, but also with the largest.

Non-fulfilment of contract may occur for several reasons. If the contract has been secured in competition with other firms, it may be that the successful one has quoted very low prices, solely to prevent other firms from getting the work, with no intention of constructing itself the engine, preferring eventually to forfeit the contract deposit.

Sometimes it is not possible to obtain delivery of the material because with variations in the cost of labour and in the cost of the raw material itself, specially frequent with fluctuations in exchange, the firm has no more interest in supplying at contract price. True, they are subject to penalties, but generally these can be eluded and in any case they do not exceed 10 per cent. of the amount of the contract. A firm can thus indefinitely postpone delivery of a certain matériel, because although there is the clause in the contract providing for cancellation in case of non-fulfilment, this is a pure formal clause which no one has yet dared to enforce.

Another instance of failure in delivering is when a firm is unable to produce the goods, and this occurs with experimental types, constituting the only case when the greatest leniency should be shown by the State, because experimental work evidently holds out difficulties quite different from that of production, and the firm which has made this technical and economic effort without succeeding in obtaining a favourable result should be assisted.

To put the aeronautical industry in an efficient state, both production and experimental work must be given continuously. The first is necessary to produce such profit as will allow a reasonable return on capital, the second is required in order to keep the technical staff up to date in progress, encouraging initiative

and permitting the acquirement of that experience which only practical construction can give.

Valuable aid can be given to the industry by the construction of spare parts and by a reasonable apportionment of repairs. These, however, should be reduced to the minimum. If a machine is seriously damaged by a fall it ought to be scrapped, because repairs would be most costly and the pilots would then have little trust in the machine. If the aircraft is slightly damaged it is better to replace the broken or damaged parts with new ones. In this way, unavoidably it is true, we order from the contractors more machines and spare parts, but this may in turn make for better prices by increasing the output and has the advantage of not returning repaired machines into service. Payments should be made promptly at delivery, for banks charge high interest on loans made to the industries.

To facilitate the expansion of the aeronautical industry it is necessary that in peace time there should be a sufficient number of firms distributed systematically over the country, who on declaration of war could very rapidly deal with the requirements of mobilisation.

These firms should therefore be sufficient in number without being excessive, as otherwise weak organic structures would be created, the maintenance of which would entail great expense.

It is essential for the development of the aircraft industry to encourage the creation of a group of auxiliary industries which depend for their existence on the principal industry and form its necessary complement. If the auxiliary industries are sufficiently plentiful, they would be of the greatest assistance in case of mobilisation.

Another essential point is gradually to induce firms to use national materials for the construction of their machines.

In time of peace, whatever appeals are made to the industries to use national material, it is certain that in practice they will purchase it where it can be obtained at lowest prices, so that while national aeronautical industries are most jealous of their claims to be selected for supplies in preference to foreigners, they may then frustrate this principle by sending orders for material abroad, thus not only damaging other national industries, but causing a prejudicial effect on the foreign exchange. It was shown at a recent inquiry that 70 per cent. of the material used in the construction of aircraft of a country was of foreign origin.

Every nation should attempt, and in fact does attempt, to build and operate aircraft with the raw material that can be obtained in its own country. Thus England, which has no wood, aluminium or petrol, is turning to metallic construction in steel and to the use of benzole which is a distillation of coal.

For Italy the question is more complex, having no coal or steel. For lubricants she could utilise castor oil, though it is doubtful whether in case of war it would be advisable to take up arable land for cultivation of the castor oil plant. For fuel a mixture of alcohol and benzine could be resorted to, but it would be impossible to be completely independent of foreign imports. For the raw materials it would be advisable to use duralumin, although the production of aluminium requires a certain quantity of fuel higher in weight than the aluminium produced, and so the problem arises whether it would not be better to import the metal direct instead of the fuel, at any rate in time of war.

7 *The Economic Elements of Production*

In order that the aircraft industry may live and prosper it is essential to have a clearly defined scheme of construction and an allotment between the various firms of the supplies in aeroplanes, engines and spare parts.

The number of productive firms must be reduced to that strictly necessary for mobilisation, that is, such as can produce sufficient supplies for mobilisation

purposes, and allowing of the rapid expansion which is called for in case of war. Every firm wishes to see its own types adopted and above all desires that the production of machines should be made by the firm which submitted the sample. This is sometimes impossible and may actually be harmful to that programme of normal work which is the foundation of industrial life.

While on one hand it is well to foster competition between constructors, both for a fair adjustment of prices and to encourage the spirit of invention on the part of their technical staff, on the other hand the sample types in each category should not be too numerous. Indeed it is difficult to pass an opinion upon a sample machine on account of the difficulty of making tests under equal conditions. The fact that the contractors are entitled to employ their own pilots is sufficient to show how difficult it is to compare the relative value of the results of the tests.

May the laws of the country impose a system of competitive tenders, it must be admitted that this system has been shown unreasonable in actual practice and in the end harmful to the very interests which it was desired to safeguard.

This position is found to exist everywhere, and the conclusion has been arrived at that it is necessary to allocate the production of supplies by direct orders to the contractors although keeping prices on a constant basis and equal for all firms.

Experimental work should be subsidised by the State, and this should be done by giving contracts for experimental machines and engines at a much higher price than that paid for ordinary engines and machines. Price competitions between various firms have proved always a failure.

When the need arises, either because the country has made no progress, or because there has been a remarkable and immediate progress abroad, it is advisable that the Government should purchase direct the licence rights of the article, which however should always be constructed by the national industry. It should in fact be a recognised and undisputed point that all the matériel employed in aviation should be a home product. Exception can only be made in the purchase of single samples for research purposes, but it would be well to avoid absolutely the purchase of even small quantities of one type, even by paying higher patent royalties when necessary. In purchasing patents abroad it must be borne in mind that some nations do not allow their industries to sell the more advanced types. In this case the purchase of licences is quite useless, as it would only involve a waste of money.

National industry ought to be protected against foreign competition, first by customs tariffs, both on wrought and raw materials; secondly, by a well-defined and constant programme of construction, which is secured by a scheme of gradual substitution of the matériel. These are the essential factors against which the price question becomes almost of secondary importance.

8 *The Importance of the Economic Factor*

The production of aeronautical supplies has a technical and economical character. It is impossible to separate the two factors, especially in case of war. It is a grave error to believe that during a war a nation can spend money without limit and can adopt the most expensive machines without considering their value. Even in the last war, which as it was conducted between two combinations of powerful nations, cannot be taken as an example, the economic factor was of prime importance, and many nations are to-day regretfully bearing the consequences.

If during the war they had paid much less to their industries for the matériel produced—and this would have been quite possible—they should not to-day be saddled with an enormous internal and foreign debt.

Aircraft and their engines should therefore fulfil not only technical requirements, but economic requirements also, so that their cost may be the lowest

possible. Less cost for the same expenditure means a larger number of aircraft or an enhanced air power.

This has been the constant concern of Germany, and it is sufficient to examine the aeroplanes captured at the end of 1917 and in 1918 to show what careful consideration must have been given to this point by the German industry.

If two machines, A and B, have very slightly different qualities, but machine B costs twice as much as A, that is, if we can have twice the number of machines A at the same price as a given number of B machines, there is no doubt that solution A is better than B. And again, supposing that a machine has been designed which gives extremely good performance, but which calls for difficult workmanship and rare materials, so that only a very few could be built, it is evident that this type cannot be adopted. Fortunately it so happens that it is always possible to obtain the highest efficiency with the most simple and least costly construction.

The engineer's skill will consist therefore in reducing the structures to their simpler and real expression, by utilising those means of production which require the minimum of labour and using the most economic materials which can be found in the country. This can be realised only by strict discipline while in time of peace, because if the engineers are submitted to rigid control in this way, but above all if the Government, by the use of the weapons and means which are at its disposal, can demand from the industries reasonable prices as against exaggerated quotations, it is evident that contractors must automatically solve the technical problem in the most economical way in order to gain an honest reward.

Sometimes it is sought to impress the public by stating that economy in matériel involves loss of life on account of the poor quality of the raw material which the industry is compelled to employ. This is absurd because aircraft are put through such tests during and after construction that were they built of material not responding to the requirements they would be condemned.

The word *economy* has here a significance entirely different from what is commonly understood. Economy should result from rational design and utilisation of the material and not the use of raw material of inferior quality.

The effect of a weapon is strictly related to the quantity available, and this holds good for any kind—guns, warships, submarines. It applies also to aircraft. The air weapon will be really effective only if a large number of aircraft can be used. If the number be limited the effect will be less, and will become negligible if an adequate number of machines cannot be put in service.

If a country allots a definite sum for its defence, the problem is how to spend it most effectively. This is true during peace time and is essentially so during war. It is not true that in war time the money question becomes secondary; in war time, above all, expenditure must be kept within the limits of the country's resources; and if this be not done the country will find itself at the end of the war in a state of slavery to the richer countries.

By the way, the examination of the air estimates of the various nations demonstrates the tendency to increase the expenditure for the personnel and relatively decreasing that for matériel. To some extent also this is a phenomenon common to all State administrations and it can only be arrested by drastic measures. It is useless to insist upon the need for the larger part of the funds being utilised for the output of matériel.

9 *Price Fixing and Cost*

The assessment of the prices of air supplies constitutes one of the most delicate tasks of the administration; for either they will be too high and the air force will weaken unless greater sacrifices are made by the country, or else they will be too low, and besides prejudicing industrial life the social level of the working classes will be lowered.

The essential point is that prices should be computed on a single basis for all, in order that differences, which are extremely harmful, shall be absolutely avoided. The price of a machine is influenced not only by its workmanship and performance, but also by the number ordered from the contractors, and such influence is very great indeed.

A good basis for determining the price of a machine is its weight. It is well to remember that there are no goods in the world that are not sold on the basis of their weight, from precious stones to precious metals, from foodstuffs to fuel, and for all materials for construction the price basis of the contract is always referred to a unit of weight; even delicate instruments like clocks are sometimes dealt with by weight. Nor are textiles and their raw material exceptions to this law, because even if these are sold in the retail trade by a linear unit, in the wholesale they are dealt with on a unit of weight.

The surest element therefore upon which to determine the price of a machine is its weight; then with sound judgment we may fix the unitary price according to the type, namely, to the material employed, to the size, to constructional details and to the workmanship it required.

Having fixed the price basis, other special factors can then be considered, to meet the objection that in aeronautics the finished article is so much better when comparatively lighter.

The fact remains that by making diagrams and tables of the unitary prices of the various types of machines and taking also into account the influence of the number of machines ordered of the same type, a curve of the costs can be plotted which will show that unconsciously we have been following that law of the weight price which is the basis of all dealings.

The basic price per pound will be so much higher the smaller and faster the machine; it will be higher for all-metal aircraft; will decrease by increasing the number ordered; will be higher for seaplanes; whilst finally the conditions of labour and the material market will be taken into account.

Sometimes the price has been arrived at by an analysis of the cost, separating that for the material, labour and overhead charges. Different criterions may be employed in compiling the analysis, but the more detailed they are the easier it is to arrive at incorrect results. In a word, the analysis of prices can be made to show whatever result may be desired.

It is remembered a firm had been asked to cancel a contract by forfeiting the supply of several machines. They submitted an analysis for compensation which exceeded the price of the machines; that is to say, the firm asked much more for not supplying the machines than was stipulated in the contract for supplying them.

10 *The Renewal of Aeronautical Materiel*

One of the most important problems of military aeronautical organisation is that of co-ordinating the number of types in service with the entry of new types, and with the duration of service of each type, so that these may be in proportion to the average life of the machines, and so that the service yielded by the said machines may be as great as possible. The different air services require necessarily different kinds of machines. At present for land work there are day fighters, night fighters, army co-operation, reconnaissance and long distance observation machines, day bombers and night bombers; whilst for naval requirements there are scouts, fleet spotters, torpedo carriers, cruising and other special planes for aircraft carriers.

The number of types is thus very large in itself, but it becomes increased by the fact that it is not possible to have in service one type only for each category as would be logical for practical and economical reasons.

It is almost impossible to have one single type in service for the simple reason that at a given moment, namely, when the new type would be ready to enter service, all the former machines would have to be scrapped and substituted by new ones.

Such replacement cannot be instantaneous, but only gradual; hence, for each category there would be in service more than one type.

The five factors bearing on the renewal of matériel are often contradictory in themselves, and for some of them we have not yet definite data. They are:—

- n Period of years between the entry of new types into service.
- c Number of types simultaneously in service.
- d Duration of service of a particular type.
- a Average life of the machines; and
- U Utilisation of the machines.

A new type may possibly be admitted into service every year, but it would not be logical to lessen this minimal period.

According to the excellence of the machine this period could be lengthened to two, three up to eight years and perhaps more, as there are types which have been in service for eight years and for which replacement has not yet been commenced.

The number of types simultaneously in service should be the least possible, so that the whoe body may be more homogeneous and supply easier.

It may be admitted that the largest number of types in service can be four.

The minimal duration of service of one type is one year, considering that it is admitted that new types shall not be submitted at periods of less than one year.

The duration in service of one type is given by the product of the number of types simultaneously in service for the period of the renewal of the type. $d = c \times n$. So that if the type is renewed every two years and two types are left simultaneously in service, the duration in service is four years.

The increase of service duration of the various types is related to the progressive standardisation of the types themselves.

While in the early years of aviation there were great differences in the area and shape of wings, in the struts, and in the controls, these are now becoming less pronounced, and we foresee in a not far distant future, machines built with few types of wings, which will be those that practice and theory indicate as the most efficient and economical.

It will come about as in the case of the Navy, that all nations will end by agreeing in the choice of types except for certain minor differences in details of design.

Another very important factor is the average life of the machine; in war the average life of a fighter was 30 flying hours, the average life of a scout 42 hours and of a bomber 60 hours.

Some machines have flown for 300 hours; others for a few minutes, crashing on taking off.

In peace time the life of machines is much longer; there are commercial machines which have flown for 3,000 hours. The life of the machine depends also upon the material of which it is built and upon the provision made to preserve the material itself.

Aeroplanes of wood would have a more limited life than those of metal, although accurate data are not available.

If the wood be well painted and doped and treated with protective coatings so as to prevent the penetration of moisture, it will last almost indefinitely.

The average life of a machine depends upon its class; thus, it is less for a fighter and in general for the small machines, but it is longer for the large ones.

We have not yet had very much experience of all-metal machines, so the more likely supposition as to the average life of all-metal aircraft is that it may be from three to six years, but it is not improbable that in the future this may be considerably lengthened.

The utilisation of aircraft depends upon the duration of the type in service and on the periods of the renewal of the type itself. Approximately the potential service of a machine is given by the formula:—

$$U = (d - n)/a$$

so that if $d = 10$, $n = 2$ and $a = 4$, the utilisation equals 2.

The essential for the economy in the service is that the value U be not less than the unit, in other words, $d - n$ should be greater than a, because on the contrary machines ought to be scrapped when in good conditions.

The utilisation of the machine is greater in proportion as the period of renewal of the type is greater.

From some numerical examples we find that if it is desired to have a frequent replacement of type, for instance 2, in order to have a reasonable utilisation from the matériel, for instance $6/a$, we must put up with a larger number of types in service, say 4; while by renewing the type at longer intervals, the utilisation is just as good with the advantge of having a much smaller number of types in service.

IV. Air Force Organisation

1 *Various Systems*

The systems of air force organisation among the greatest Powers are three in number:—

(*a*) Independent; constituted in an autonomous Ministry similar to the Ministry of War and of the Navy.

(*b*) Air services of the Army, of the Navy and of civil aviation, divided among the corresponding Ministries with the respective technical organs.

(*c*) Air services of the Army and of the Navy divided among the corresponding Ministries with a single technical body attached to the Civil Aviation Service.

These various systems have their own advocates and offer advantages and disadvantages.

The second system has the advantage of supplying the Army and Navy with their auxiliary air services, employing their own personnel. The disadvantages lie in the duplication of the technical departments, in the competition which will arise in the industrial production and in an indifference to the use of the air arm as an independent entity. From such an organisation, therefore, there may arise a neglect of those offensive and defensive actions which during war can be carried out by enemy's air forces independently of the army and the navy.

In the first organisation there are, instead, the opposite advantages and defects, namely, that the army and navy co-operation services are considered of minor importance, whilst much greater weight is given to the independent air force.

The third system possesses perhaps more outstanding advantages over the first two, except for the lack of an independent air unit.

The creation of an Air Ministry may be regarded as absolutely necessary at the present time in order to ensure aeronautical progress, as otherwise the army and the navy would regard the air arm merely as an auxiliary force and not as one of equal value.

Some consider, however, that it is not unlikely that with the advance of aeronautical science, which will render easier the control and use of machines, thus minimising the importance of piloting, we shall reach a solution that respects the wishes of the army and navy while leaving intact the constitution of the independent air force.

An Air Ministry should, for this reason, undertake the organisation of the independent air force with a technical service capable of supplying the two Ministries of War and Navy with the matériel necessary to them. These would then provide for its use with their own personnel.

2 *Civil Aviation*

As to civil aviation, in course of time it could be left to the Ministry of Transport, as above indicated, especially if in its present form.

It is feared by some, in fact, that civil aviation if administered by a military authority will end in being sacrificed and neglected.

The example of the United States is frequently cited in this connection. The Post Office Department undertook the operation of the first air mail services and it succeeded in arranging in a few years the greatest world line, from New York to San Francisco, a distance of over 1,000 miles, running every day there and back, flying by day and night.

Civil aviation is much more important for the country's defence than the mercantile marine is for naval defence, because of the fact that while civil aircraft can be transformed into bombers, merchant ships can, in time of war, only render auxiliary service and not undertake any offensive actions.

Air transport services must at present be subsidised as working expenses are higher than revenue. State aid ought, however, to produce the greatest possible useful effect.

We have here the same difficulty met with in the subsidy of maritime services. At one time subsidies were granted in such a way that the vessels had no interest in the transport of passengers and goods, but preferred running in ballast.

The subsidy to air transport should be granted on the basis of hours of flight and the weight carried, that is, on passenger-mile and ton-mile.

The companies, however, have demanded that also the engine power should be taken into consideration, because this would favour the progress of aeronautical science, causing the companies to keep on increasing the power of their machines. But this would be allowed for in basing the subsidy on the ton-mile and passenger-mile, because the more powerful the aircraft the speedier it will be and greater distance could be covered in the same time.

After the initial period of practical experience two great air Powers, Great Britain and Germany, have come to the conclusion that it is better to combine in one concern all the commercial air transport companies, with the advantage of reducing general expenses and overhead charges, of obtaining uniformity in the types of machines and in the treatment of the personnel, and rendering business transactions with the Government easier.

Air transport ought essentially to compete with that by sea and rail over long distances, and therefore nearly all the air Powers are endeavouring to arrange international agreements which will allow them to operate air lines beyond the confines of their own countries. Even Germany, which up to recently has been unable to do this owing to the restrictions imposed upon her by the Versailles Treaty, can now extend her services beyond her frontiers.

One of the principal reasons for which air transport has not been as widespread as it was expected is that the average rapidity on long journeys is not much higher than that of other means of transport, or at least not such as to compensate for the greater risk. Railways have the advantage of being able to

travel day and night with an average speed of 35 miles per hour and over long routes. The range of action is, as it were, infinite, for a change of locomotive or refueling can be made in a very short time.

Steamers have the double advantage of straight line routes and large range of action, being able, in addition, to travel day and night in any weather.

The aeroplane, however, although having a speed so much greater than the train or steamer, can at present only be used by day, cannot fly in very bad weather and has a very limited range, being compelled to make frequent landings.

On a very long journey, by daily stages, the average speed is not more than 50 miles per hour, which is the same as the train. For short journeys the advantage of speed is reduced by the time required for reaching the aerodrome from the middle of the town and vice versa.

A notable example is the crossing of the American Continent which can be made in 72 hours by train and requires not less than 30 hours by aeroplane, flying day and night, and nearly 50 hours if flying only by day and running by train at night.

On the other hand, there is no doubt that aircraft will triumph over all its competitors when decisive improvements will be achieved and that in a very few years air navigation will become the most common means of transportation.

V. Conclusion

In order that the air arm may truly fulfil the object for which it is created and make good the financial sacrifices that the country must bear, it is necessary that a close collaboration should take place between the engineer, the pilot and the manufacturer.

It is necessary further that the principals should have a full knowledge of all technical and economic problems concerning aeronautical service so that decision be taken by them upon their own practical knowledge without having to refer for advice to the lower personnel. This does not refer to the political head of the service who has to direct the general policy of the Air Force.

For all members of the Air Force frequent flying is an indispensable necessity.

It is necessary that the personnel should have the certainty of stabilisation in air organisation, that the most rigid discipline be maintained in all ranks, that the principals possess the necessary ascendancy over their dependents in order to enforce those orders which are considered essential. Above all in aeronautics it is a dangerous practice to try to improve what appears already satisfactory; we must not therefore claim from the air industry extraordinary results and time must be allowed for development; one must not place too much faith in glowing accounts of exceptional improvements which are frequently biased.

Only by slow and methodical work it is possible to attain in personnel and matériel, not perfection, but that capacity and that quality which is to be expected.

Critics must always remember that it is much easier to criticise than to do.

The empty places which death makes in the ranks should only serve as warnings that those who dedicate themselves to aviation must be able to shoulder a great responsibility towards themselves and towards others, and that they should contribute to their profession all their activities in order to gradually attain that final development which will be the inheritance of future generations.

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(*Prepared by R.T.P.*)

AIRCRAFT ENGINES, FUELS AND LUBRICANTS

I Fuels (Characteristics and Production)

Physical-chemical study of light fuels and of lubricants in Aeronautics. (M. Moutte, La Technique Aeronautique, Sept.-Oct., 1926, pp. 279-281 and 305-319.) (8.51/5096 France)

Systematic tests of fuels in an engine on the test bench were commenced in 1917, in conjunction with a systematic determination of physical properties, and as far as possible of chemical composition. It was found that homogeneity, volatility and high latent heat of evaporisation were the most desirable qualities. In agreement with Ricardo, the aromatic compounds of hydrogen are found to be the least amenable to propagation of explosion, then the saturated cyclic compounds, and lastly the saturated acyclic compounds. In identifying fuels use is made of characteristic curves of distillation :—

Temperature—Volume Distilled, Density—Volume Distilled.
Temperature—Density, Temperature—Solubility.

Temperature of distillation plotted against critical temperature of solubility in aniline gives highly characteristic differences, and is considered a fundamental method. Optical methods are also used for approximate quantitative determination. The formation of clouds of condensed drops affords another method of determination. The mechanical conditions were also examined :—Variation of inlet pressure, condensation, centrifugal separation.

Lubricants offer mixtures of a higher order and are much less amenable to the method described. In our almost complete ignorance of the physical nature of lubrication and its relation to the physical properties of lubricants, viscosity, surface tension, solubility, an empirical method is imposed. The suitability of a particular lubricant is established by tests under working conditions and the same brand is used in so far as it can be specified and identified. Identification is easy with vegetable oils, but brands of mineral oil sold as identical show great differences under the test of solubility in aniline. The thermal properties of the lubricant, in combustion, enter into the complete problem.

Volatility Tests for Fuels. (T. S. Sligh, J. Soc. Automotive Engineers, August, 1926.) (8.51/4934 U.S.A.)

Elementary theories regarding the evaporation characteristics of pure substances and mixed liquids are discussed briefly. The difficulties are pointed out which are likely to be encountered in attempts to calculate the distillation characteristics of motor fuels from data relating to pure substances or in extrapolation from the atmospheric boiling-range of the fuel to the range of temperatures encountered in utilisation. A brief review of previous methods of arriving at fuel volatility is also presented.

Volatility, as applied to motor fuels, is defined as being measured by the percentage of a given quantity of the fuel which can be evaporated under

equilibrium conditions into a specified volume. The weight of air under known pressures is taken as a convenient measure of the volume.

The new method described is an equilibrium distillation of the fuel in the presence of a known weight of air. The fuel is supplied at a predetermined rate by displacement from a reservoir by the fall of a clock-controlled cylinder, and flows into a long metal helix immersed in a bath at the temperature of the test. Air is also delivered to this helix at a predetermined rate, as measured by a small orifice meter. Evaporation takes place to equilibrium, and the uncondensed fuel is drained from the lower end of the helix and measured. By such means the distillation curve for the fuel in any desired air-fuel mixture can be determined accurately.

Data are presented for five fuels of varied characteristics which had also been used in engine tests of starting volatility. Such volatility data will be useful in connection with studies of engine performance, carburation, the blending of fuels, and the production of fuels for specified performance.

The Bergius Process for Coal Liquefaction. (Paper read at the International Conference on Bituminous Coal, Pittsburgh, U.S., by Dr. Bergius. Paper described in Automotive Industries, Nov. 25th, 1926.) (8.511/4959 U.S.A.)

Dr. Bergius describes the general principles and operation of his method of obtaining light fuel from coal. The development of this process in Germany is stated to have passed the experimental stage. One short ton of bituminous coal is stated to yield 45 gallons of light spirit containing a very large quantity of aromatic and hydro-aromatic compounds, having good anti-knock qualities.

The Vapour-phase type of cracking process in relation to production of anti-knock fuels. (W. G. Leamon, J. Soc. Automotive Engineers, Vol. 20, No. 1, page 67, Jan., 1927.) (8.512/4949 U.S.A.)

In the opinion of the author, cracking processes of the future will be of the vapour-phase type which give a product far superior in its anti-knock properties. A particular vapour-phase product known as Stellarene consisting almost entirely of the two series olefin and naphthalene, and produced by the breaking up of large molecules in the vapour phase in the presence of a catalyst, is described in detail.

Recent developments in coal utilisation. (C. H. Lander, Mechanical Engineering, Vol. 49, No. 1, page 1, January, 1927.) (8.51/4946 U.S.A.)

The author describes some methods for obtaining light spirit from coal, particularly the work carried out in Great Britain.

Production of petrol substitutes from coal. (A. C. Fieldner, J. Soc. Automotive Engineers, Vol. 20, No. 1, page 98, January, 1927.) (8.51/4947 U.S.A.)

This article is a summary of the present position regarding the production of petrol substitutes by the following means :—

(*a*) High temperature carbonisation of coal.
(*b*) Low temperature carbonisation of coal.
(*c*) Hydrogenation of coal.
(*d*) Synthesis of hydrogen and carbon monoxide gases derived from coal, resulting in the production of alcohol.

Dopes for fuels. (E. Sokwell, U.S.A. Patent Specification No. 12219, May 11th, 1925.) (8.514/4965 U.S.A.)

The specification covers the use of the metals, lead, antimony and tellurium, and others (excluding zinc) having melting-points between 300°C. and 700°C.;

and the chemical compounds, lead carbonate, basic copper carbonate, calcium carbonate, sodium carbonate and potassium carbonate.

Fuel from the service standpoint. (T. A. Boyd, J. Soc. Autom. Eng., 18, 641-8 (1926). Abstracted in Chem. Abs., Vol. 20, No. 21, p. 3555.) (8.51/4897 U.S.A.)

The nature of gasoline and the sources of the world's supply are discussed. Service problems arising from the use of gasoline include resin formation, dirt accumulation and the presence of water. Remedies are discussed.

(*Voltol*—see Compositions.)

2 *Heavy Oil Engines*

Heavy Oil Aviation Engines. (Hans Woltereck, Illus. Flugwoche, Oct., 1926, pp. 519-522.) (12.81/5097 Germany)

The author summarises the relative production and price of light and heavy oils, the latter costing about one-fifth of the former, and offering almost complete immunity from fire.

The essential difficulty lies in carburation, and the problems are discussed of producing a sufficiently intimate mixture internally or externally.

The results obtained on the Bagnulo engine of the firm Spa, Turin, are given :—Thermal efficiency 30 per cent. (for. sp. gr. 0.88 and 9800 cal./kg.), consumption 230 grams per h.p. hr. in a 35 h.p. engine. The vaporiser is of the external hot bulb type.

Model heavy oil two-stroke engine constructed by Santos Dumont. (L'Aerophile, August 1st-15th, 1926.) (12.81/4627 France)

Santos Dumont in company with M. Soriano has constructed a small heavy oil engine with which remarkable results have been obtained. The bore is 30 mm., the stroke 25 mm., and the engine develops $\frac{1}{3}$ h.p. at 4,000 r.p.m.

The most important feature of the engine is that it runs on heavy oil, thus eliminating fire risks. The engine is of the two-stroke type and the cylinders are cooled by the carburated gases which ensures vaporisation of the heavy oil. The engine can be forced up to 8,000 r.p.m. without detrimental results. The weight with the flywheel and carburettor is only 650 grammes ($1\frac{1}{2}$ lbs.).

3 *Torsional Vibrations in Crankshafts*

The properties of torsional vibrations in reciprocating engine shafts. (Dr. G. P. Goldsbrough, Proc. Roy. Soc., Series A, Vol. 115, No. A.764.) (8.22/4971 England)

The author has previously studied the torsional vibrations occurring in a reciprocating engine shaft for the case of a shaft driven by a six-cylinder engine, all parts excepting the shaft being considered rigid. (Proc. Roy. Soc. A, Vol. 109, page 99.)

The present paper describes a model which was set up to produce the characteristics of a reciprocating motion. As a result of the experiments with this model, the following torsional effects appeared with variation of speed :—

1. The shaft is subject to vibrations at all speeds, but within a certain range defined by a formula given in the paper the vibrations are unstable and of large amplitude. This range may be considerable when the piston is relatively heavy. The frequency of vibration is once per revolution of the shaft.

2. At a lower speed the vibrations are again unstable but over a much smaller range. Superimposed upon them is a forced vibration which increases slowly to a maximum at the beginning of the range and then diminishes rather more slowly. This is in marked contrast to the case above, where the rise in amplitude is sudden.

The frequency of vibration is twice per revolution of the shaft.

3. At still lower speeds there may be other ranges of instability of much smaller extent. They were not observed during the experiments.

4 *Balancing*

Balancing of masses in high speed rotation. (Viktor Blaess, Darmstadt, Z.f.M.u.M., December, 1926, pp. 429-448.) (8.22/5098 Germany)

The differential equations are solved for a variety of conditions (out of balance masses, elastic supports or foundations) and elucidated graphically. Test methods are discussed, and the importance of systematic investigation of high speed machinery is emphasised.

5 *A Turbo-Motor with Compressor Run on Naphtha*

(A. Guidoni, Notiziario Technico, No. 8, August, 1926.) (8.62/4954 Italy)

The author suggests the adaptation of the Ratto supercharger based on a cycle taking place in three parts, namely, a centrifugal compressor, a cylinder, and a turbine. By this means the compression and expansion at low pressures are carried out in rotary systems, whilst compression and expansion at high pressure and temperature are carried out in a reciprocating system. In the type of engine proposed, the mixture is compressed in a cylinder, in which a preliminary expansion of the gases driven off as a result of combustion and intended to drive the turbine takes place so that these gases reach the blades of the turbine at a temperature much lower than that of combustion. It is estimated that the weight should not exceed 2.2 lbs. per h.p.

6 *Ignition Systems*

Electric Characteristics of Spark Generators for Automotive Ignition. (R. B. Brode, D. W. Randolph and F. B. Silsbee, N.A.C.A. Report No. 241.) (8.91/5048/U.S.A.)

This paper reports the results of an extensive programme of measurements on eleven ignition systems differing widely in type. The results serve primarily to give representative data on the electric and magnetic constants of such systems, and on the secondary voltage produced by them under various conditions of speed, timing, shunt resistance, etc. They also serve to confirm certain of the theoretical formulæ which have been proposed to connect the performance of such systems with their electrical constants, and to indicate the extent to which certain simplified model circuits duplicate the performance of the actual apparatus.

AERODYNAMICS

7 *Fluid Motion*

The laws of similitude in viscous fluid motion. (Prof. Camichel, Directeur de l'Institut Electrotechnique de Toulouse. Translated in Engineering, January 7th, 1927, pp. 27-30.) (5.32/5099 France)

Particles of metal dust with attached air giving the exact density of water are illuminated with regular intermittence. At comparatively low speeds quasi

steady motion, *i.e.*, with region of steady cyclic flow, were made visually observable.

The photographs are among the clearest yet produced, and illustrate possible varieties of configuration of flow behind an obstacle in a very striking manner. Where the path of each particle appears as a broken line, the velocity can be measured in every part of the field.

The conclusion is drawn that the laws of similitude hold for the new configurations of flow studied. In the introductory sentence the author expresses his belief in Helmholtz's view that the equations of viscous fluid motion are exact expressions of the laws which govern fluid motion.

Laws of the Frequency of Alternate Vortices detached behind an Obstacle. (H. Benard, Comptes Rendus, 182, pp. 1375-1377, June 7th, 1926. Abstracted in Science Abstr. A, November 25th, 1926, No. 347.) (5.32/5044 France)

The formula representing the results of a long series of observations is $N=(0.430)\,(V-166)/(D+0.307)$ c.g.s. unit in which N=frequency, V=velocity, and γ=kinematic viscosity. This does not obey the laws of dynamic similitude. Irregularities in the spacing of the vortices are present in most cases, although great care was taken to have the water quite quiescent before an experiment, and the times taken for the vortices to delay are also capriciously unequal.

The Inexactness of the Theoretical Laws of v. Kármán for the Stability of Alternate Vortices. (H. Benard, Comptes Rendus, 182, pp. 1523-1525, June 21st, 1926. Abstracted in Science Abstr. A, November 25th, 1926, No. 347.) (5.32/5045 France)

The author's experiments do not bear out the laws of v. Kármán. In particular, the ratio of the distance between the vortices to the distance between the rows is not constant and equal to 0.283, but varies from 0.23 to 0.59, with a mean of 0.44. The other ratios, that of velocity of vortices to velocity of obstacle, and between spacing of vortices and width of obstacle, also vary between wide limits.

Disagreement between observed distances of alternate vortex cores behind a cylinder in a viscous fluid stream and the distances derived from v. Kármán's theory of a stable vortex train by the principle of dynamical similitude. (H. Benard, Comptes Rendus, 1926, Vol. 183, No. 1, pp. 20-22, and Zurich Congress for Applied Mathematics, 1926.) (5.32/5100 France)

The author reduced some 20,000 observations on the motion of Metaxylol, water, and sugar solutions of two densities, by the usual methods.

He obtained four distinct curves, one for each fluid, and concluded that v. Kármán's theory was untenable.

In replying, v. Kármán pointed out that the small scale of the experiments and the existence of a free surface introduced the formation of ripples under forces of surface tension and gravitation. Further, the empirical equation given by H. Benard for correcting v. Kármán's formula was dimensional, and would give different values for different sets of units. On making the formula non-dimensional by means of gravitational and surface tension coefficients, v. Kármán found, by this extension of the conditions for dynamical similitude, the same correction factors as those obtained experimentally by H. Benard.

He concluded that the discrepancies arose from not taking into account all the relevant physical properties of the fluids employed in the experiments, in applying the principles of dynamical similarity.

Hydrodynamical Theory. Three papers on convection of vorticity.

(i) Results from the Göttingen Aero. Lab., 2nd issue, 1923, pp. 69-77. (5.32/5101 Germany)

The spread of a uniform jet in the surrounding air was explored by a self-recording wind speed meter.

The record at the source of the jet is nearly rectangular, but with increasing distance down stream the jet steadily broadens at the base and narrows at the summit until a symmetrical peak is formed. Thereafter the height of the peak diminishes as the base broadens.

(ii) Report on experiments as to the spread of turbulence. (Prandtl, Z.f.a.M.u.M., April, 1925, pp. 136-139.) (5.32/5102 Germany)

Empirical expressions are developed for the rate at which the phenomena proceed in the experiments described above.

The conceptions of elements of fluid in vortical motion (Flussigkeitsballen) of mean convection paths (Bremsweg, Mischungsweg) and of mean convection velocity (Mischgeschwindirkeit) are introduced.

The results are related to v. Kármán's empirical expression for turbulent resistance in a pipe.

Further developments are referred to statistical values determined by the theory of probability.

(iii) Calculation of rate of spread of turbulence. (Walter Tollmien, Z.f.a.M.u.M., December, 1926, pp. 468-478.) (5.32/5103 Germany)

The author expands the analysis given by Prandtl in (ii) and makes a comparison with the experimental results given in (i).

He claims good agreement between empirical equations and experimental facts.

Completely turbulent flow. (Prof. L. Prandtl, 2nd International Congress of Applied Mathematics, September, 1926.) (5.32/5104 Germany)

The actual configurations of flow in a turbulent fluid are so involved that there is little hope of achieving a detailed analysis. On the other hand, it appears instructive to seek methods of predicting the mean values of velocities and tangential pressures in turbulent flow. After various failures the author arrived at results capable of formulation as follows:—

1. *Theorem.*—Starting from H. A. Lorenz's formulæ for apparent pressures in turbulent flow, the fluctuations of the velocity will be estimated as follows:—u' (longitudinal) $= l\,(d\bar{u}/dy)$ where $\bar{u}$ = mean velocity, y the transverse ordinate, and l a characteristic linear dimension defined as the convection path (Mischungsweg), that is the path traversed before an element of fluid (flussig keitsball) is blended with its new environment.

The transverse velocity v', which is derived from previous encounters, may be taken as proportional to u'. The apparent tangential pressure is given by $xy = lu'v' = C\rho l^2\,(d\bar{u}/dy)^2$ where C is a numeral coefficient.

Putting terms of this type in the equations of hydrodynamics it is easy to see that the resistance is proportional to the square of the velocity.

The magnitude of the convection path l can be deduced from observations, and in certain cases predictions may be made about the path traversed by individual elements before they lose their identity by general diffusion.

In the case of a jet issuing from a hole with consequent turbulent increase of the diameter of the jet, the convection path is proportional to the distance from the hole.

The tail (or shadow) behind a strut set at right angles to the stream had a width proportional to $\sqrt{(x.d)}$ where d is the initial width and x the distance down stream. If we assume that l is independent of the transverse distance as seems likely, distributions of velocity are obtained closely resembling observed facts. The numerical factor is, however, only obtainable empirically. The normal component of velocity normal to the channel walls diminishes to zero at the walls.

The relation between velocity and distance so far cannot be obtained from first principles. For smooth tubes Blasins gives $\bar{u}xy^l/l$, but we must put lxy^l/l to obtain consistent results, and this relation has not yet received any physical interpretation. For non-circular pipes further assumptions must be made as to cross flow. The important question whether the boundary layer adheres to the walls or leaves them can be attacked numerically, but hitherto no satisfactory experimental verification has been obtained.

The Multiplicity of Solutions in Aerodynamics. (M. Dupont, Ing. des Arts et Manufactures—La Technique Aeronautique, December 15th, 1926, pp. 354-371.) (5.32/5105 France)

By multiplicity of solutions the author signifies the variety of analytical forms required to express the variety of configurations of flow possible with geometrically similar rigid boundaries at different values of Reynolds' number. He reproduces a figure given by Marchis showing the resistance of a body as a function of Reynolds' number as a unicursal curve, sudden variations in the curve corresponding to instability of the configuration of flow at the given value of Reynolds' number, in accordance with the usually accepted view.

A number of experiments and hypotheses are assembled in an attempted synthesis of the theory of aerofoil lift and drag.

Forces on a Cylinder in a Stream of Viscous Fluid. (Prof. L. N. G. Filon, Proc. Roy. Soc., A.113, November, 1926, pp. 7-27.) (5.32/5106 England)

The author uses a more general analysis than Oseen, Lamb and Bairstow, and restricts consideration to the more tractable problem of motion at a distance from the cylinder.

Disturbing components of motion of order $r^{-\frac{1}{2}}$ are confined to a tail of width of order $r^{\frac{1}{2}}$, so that the relative momentum imparted to the wake is finite.

The author establishes the theorems that the lift is the product of density, circulation at a distance and stream velocity (Kutta Joukowsky's theorem) and that the drag is equal to the increase of momentum in the tail at a distance. The latter result has been assumed as approximately true by Prandtl and others.

Experimental solutions of hydrodynamical problems. (Prof. E. P. Hahn, Zurich International Congress, September, 1926. Trans., Engineering, February 11th, 1927, pp. 178-180.) (5.32/5107 Switzerland)

The method of determining current fields in an electrolytic tank similar to velocity fields round aerofoils is extended to the much more involved problem of determining the field in a water turbine with axial supply, rotatory blade motion, and peripheral discharge.

Three irrotational fields are determined separately and then are superposed, the intensities being chosen so that the circulation round the individual blades brings the dam point or dead water point to the blade tip. The result is unexpected. The streamline leaving a blade tip doubles back sharply close to the blade, suggesting the probable formation of a permanent eddy region at the blade tip.

8 Heat Transfer

Heat Transfer from liquids or gases to solid walls. (Professor A. Stodora, Schweizerische Bauztetung, Vol. 77, No. 18, abstracted in Mechanical Engineering, Vol. 49, No. 1, page 58.) (8.35/4944 Switzerland)

The purpose of this article is to extend existing theories on this subject, and in particular to determine the consideration that should be given to the frictional heat due to turbulence. Reference is made to previous publications by Prandtl, von Kármán and others.

The author starts with von Kármán's differential equation for the thickness of the limit layer. He shows that the heat transfer due to wall friction, for which he gives a mathematical expression, is materially affected when there are present a high velocity of flow and a small temperature difference between the wall and the gas. He discusses next the influence of the laminar boundary layer, which he defines as the layer located between the wall and the turbulent layer. Its thickness is determined by the requirement that at the sheet of separation the laminar layer friction must coincide with the turbulent friction. He comes to the conclusion that in gas flow the laminar layer transmission to the wall affects the heat transfer only to an insignificant extent, but in the case of liquid flow it has a material influence in the direction of reducing the transfer of heat.

Heat transmission in fluids. (M. Ten Bosch, Ver. deu. Ing., 70, 911-914. Abstracted in Engineering Abstracts, No. 29, October, 1926.) (8.33/5082)

The author points out that at present only empirical formulæ exist for the rate of heat transmission between various liquids and the walls of their containing tubes, although a single expression can be used in the case of all elastic fluids. He develops a general formula which covers both liquids and gases, and applies it to experimental results obtained by Mr. W. Stender on the flow of water through smooth-bore pipes. The coefficient of heat transmission α is assumed to depend upon the kinematic viscosity v, the coefficient of viscosity η, the specific weight Γ, the coefficient of conductivity λ, the specific heat at constant pressure Cp, and the diameter of the pipe d. The analytical reasoning is based upon two functions, the Osborne Reynolds function vd/v and a function attributed to Peclet

$$vd\lambda/C\tfrac{1}{2}r=P.$$

The final relation takes the form $\alpha\,(d/\lambda)\,(B)=b\,(P)\eta$ and the author gives curves to assist in the evaluation of some of the variables in B.

Heat transfers in the boundary layer of flowing gases. (Dr. W. Ludowici, Z.V.D.I., Vol. 70, No. 34.) (8.35/4937 Germany)

According to Prandtl and von Kármán all the factors determining tangential friction and heat transference are contained in the thin boundary layer. Beyond this layer the flow rapidly approaches the potential flow condition. With a laminar boundary layer, the whole heat transference process is covered by radiation, conduction and convection, but in the case (von Kármán) of the turbulent boundary layer, vortex motion brings in another factor influencing the propagation of heat, namely, the conductivity of the turbulent motion.

Apparatus is described and illustrated for testing the various theories of heat transfer. Results of the tests are given and are in good agreement with theory.

9 Wind Channels

The Laboratory at Quatro Vientes. (Aerea, September, 1926, J. LI. S.) (11.11/5108 Spain)

The channel is of the Eiffel jet type, but to conserve the energy there is a large return passage along the upper storey of the building.

A Fiat engine of 700 h.p. driving a screw of 3.7 m. diameter at 700 r.p.m. produces a jet speed of 55 m.p.s. Details are given of the mounting balances,

etc., used, particularly Herrera's cycloidal manometer of constant sensitivity for all ranges of speed. (The diameter of the jet is not given, but is stated to be 3 m. in *Notiziario Tecnico.*)

Three Japanese Wind Tunnels. (Report of the Aeronautical Research Institute, Tokyo Imperial University, Vol. II., Part I., page 4, table II.) (11.11/5109 Japan)

(*a*) Technical Department of Board of Military Air Service.
(*b*) Aeronautical Research Institute.
(*c*) Aeronautical Research Laboratories, Imperial Japanese Navy.

	Dia. of Jet.	Power.	Speed Range.
(*a*) Jet, double return channel (Crocco)	1.75 m.	100 h.p.	10-25 m/s.
(*b*) Jet, single return channel (Prandtl)	1.20 m.	20 h.p.	4-24 m/s.
(*c*) Jet, no return channel (Eiffel) ...	1.25 m.	100 h.p.	3-50 m/s.

Czecho-Slovak Aerodynamical Laboratory. (L'Aero Sport, No. 547, November 4th, 1926.) (11.11/4964 Czecho-Slovak)

A general description of the laboratory is given, including a detailed account of the wind tunnel, which is of the Eiffel type.

The Jurieff Compound Wind Channel (Moscow). (Nachrichten fur Luftfahrer, September 28th, 1926.) (11.11/5110 Russia)

This design was evolved by Jurieff with a view to obtaining a bigger and longer channel, utilising the already existing small tunnel, without going to the expense of constructing an entirely new channel. The small channel was connected by extending the exit cone, with a large working section permitting of larger models being tested.

The first working section (in the small channel) is 0.75 metre (2ft. 6in.) with a diameter of 0.375 metre (14in.), whilst the large working section is 2.2 metres (7ft. 2in.) long and 0.7 metre (2ft. 4in.) in diameter. The air is sucked into the small entrance cone; it then flows through the small working section and the diverging cone, and then through the straightening device to the large working section. The air is expelled into the open through a circular channel by means of a fan. The tests at the "Tsagi" Central Aerohydrodynamical Institute, Moscow, of a model to scale 1 : 8 gave good results and showed only slight pressure losses. It was found, however, impossible to use the second working section with the diverging cone left at its full length.

Special baffles were fitted in front of the entrance cone as suggested by Joukowsky, but they did not give good results and were removed.

Wind Tunnel Standardisation Disc Drag. (M. Knight, N.A.C.A. Technical Note No. 253.) (11.17/5078 U.S.A.)

This report deals with the resistances of a series of three similar discs placed normal to the wind as determined in the atmospheric wind tunnel of the National Advisory Committee for Aeronautics. This is the first of the standardisation tests to be made in American wind tunnels using these particular discs. The curves of drag coefficient plotted against Reynolds' Number for this tunnel show discrepancies between overlapping values which are to be attributed to the presence of the tunnel walls.

10 Pressure Distribution Over Wing Surfaces

The effect of tube length upon the recorded pressures from a pair of static orifices in a wing panel. (T. Carroll and R. E. Mixon, N.A.C.A. Technical Note No. 251.) (11.18/5077 U.S.A.)

This investigation was instituted to determine the effect of tubing length upon the indicated pressure values as ascertained in the pressure distribution measurements upon the PW-9. The purpose is to determine the percentage of

error in the pressure readings which might be caused by various lengths of tubing between the pressure orifices and the pressure cell at the manometer.

Measurements show that the shortest distance between an orifice and its corresponding pressure cell on the PW-9 airplane is 4ft. 9in., this orifice being No. 4 U.R. which is located on the upper surface of the right upper wing panel adjacent to the centre section strut fittings. The longest distance, 18ft., is between the outermost and rearmost orifice in the left elevator and its corresponding pressure cell.

Influence of the orifice on measured pressures. (P. E. Hemke, N.A.C.A. Technical Note No. 250, November, 1926.) (11.18/4953 U.S.A.)

The object of this paper is to determine the influence of different orifices on the result of measuring the same pressure distributions and deals with the effect of orifice size and shape on a pressure recorded at a designated point on a body placed in an air stream. This effect was measured by making pressure distributions over a circular cylinder placed in an air stream, so that its axis is perpendicular to the direction of the stream. It was found that the pressure on the greater part of the up-stream half of the cylinder apparently increases when the orifice size increases; the pressure measured on the down-stream half of the cylinder does not change for the orifice sizes used in the tests. Rounding the edge of the orifice has the same effect as increasing its size.

The maximum ratio of orifice diameter to radius of curvature of the surface in the plane of motion, for which no measurable error was found, is given. Values of this ratio for orifices as used in aircraft and model airfoils were found to be much less than the maximum ratio.

Pressure distribution for U.S.A. 27 Aerofoil with square wing tips. (C. G. Heard, Mechanical Engineering, Vol. 48, No. 12, page 1401, December, 1926.) (5.336/4943 U.S.A.)

Wind tunnel tests were undertaken to determine the distribution of loading over a U.S.A. 27 Aerofoil with square wing tips. The effect of stagger on the distribution of the loading was found to be considerable. As the stagger increased the load on the upper wing increased, while that on the lower wing decreased; the ratio of the load on the upper wing to that on the lower varying from 1.02 with no stagger to 1.52 with 30° stagger at 0° incidence.

11 *Airscrews*

Numerical Calculation of Thrust and Efficiency of Airscrews under arbitrary working conditions. (Th. Bienen, Z.F.M., November 27th, 1926, p. 485.) (5.41/5111 Germany)

With reference to previous papers (Bienen and v. Kármán's "Theory of Airscrews," Z.d.V.D.I., 1920, p. 1237, and Th. Bienen, "The best distribution of lift over airscrew blades," Z.F.M., 1925, parts 10 and 11) a method of rapid approximate determination of airscrew characteristics is given.

The method is based on Prandtl's note to A. Betz's "Screw propeller with least energy loss," Nachrichten d. Gresell d. Wiss., Göttingen, 1919, p. 1923, Prandtl gives as mean induced axial velocity

$$W \text{ mean}/W \text{ effective} = 1/II \cos^{-1} e - (\{R-r\}/R)\ N/\sin B'$$

N = number of blades. B' = induced incidence.

The airscrew with a finite number of blades may be replaced by an equivalent airscrew with a very large number of very narrow blades of the same total width. The diameter of the airscrew must, however, be reduced in accordance with Prandtl's formula

$$R \text{ reduced} = R\ (1 - 1.39 \sin B'/N)$$

Excellent agreement was found between the predicted and measured distributions of velocities and pressures at the Aix-la-Chapelle laboratories.

Tests of 13 Model Propellers. (W. F. Durand, N.A.C.A. Report No. 237.) (5.42/4764 U.S.A.)

These propellers were tested to determine the performance coefficients and characteristics for certain selected propellers of form and type commonly used in the U.S. Navy.

Airscrew with variable pitch and variable diameter. (M. G. Rouilleit, Les Ailes, November 7th, 1926.) (5.43/4960 France)

A method of varying the pitch and diameter of an airscrew is described in detail. It is stated that the device controlling the blades can be easily fitted inside a fairing of normal proportions and can be adapted to any engine.

12 Gyroplanes

Experiments on a "windmill plane" (Windradflugzeug). (R. Seiferth, Göttingen, Z.F.M., Vol. 22, p. 483.) (17.3/5112 Germany)

The model has 60 cm. diameter and is geometrically similar to the Spanish model tested at Cuatros Vientos. A special hub carrying the four blades attached by flat springs is mounted on a T-piece with a divided quadrant permitting a variation of disc incidence from 0° to 90°. Two profiles were tested, Göttingen 429 (symmetrical) and 387 (cambered). Disc coefficients were determined for lift, drag and moment.

The results are transformed to full size and give the following characteristics: Power 120 h.p., maximum speed 26 metres p.s., maximum climb 1.05 metres p.s., landing speed 13.5 metres p.s., vertical descent 11 m.p.s., glide of least vertical descent 20°, vertical component 5.7 m.p.s.

The figures agree roughly with full scale tests except for vertical descent, where the full scale tests appear to give about half the figure for model tests.

13 Effect of Protruding Gasoline Tanks Upon the Characteristics of an Aerofoil

(Eastman N. Jacobs, N.A.C.A. Technical Note No. 249.) (5.33/5049 U.S.A.)

Uncertainty as to the effect of a petrol tank protruding from the centre section of a wing upon the aerodynamic characteristic of the wing has led to the testing of such an arrangement in the variable density wind tunnel. Tests were made only at the highest value of the Reynolds' Number on which the tunnel is normally operated. A Clark Y aerofoil section was employed and the tank was made to represent roughly that used on a "Moth."

The results of the tests show clearly the importance of considering interference effects arising from objects which protrude from the lower or the upper surface of an aerofoil. The particular case investigated indicates that the detrimental effect is less when the object protrudes from the lower surface.

14 Aeroplane Stability

Theory of lateral motion of an aeroplane. (R. Fuchs and A. V. Baranoff, Report of the German Aeronautical Research Laboratory, E.V., Berlin, Adlershof. Z.F.M., January 28th, 1927, pp. 32-40.) (7.21/5113 Germany)

The work is a development of Fuchs' and Hopf's "Aerodynamik," Chap IV.

The coefficients of yawing and rolling moments are developed in Taylor series in terms of coefficients of lift, drag, aileron moment and rudder moment. Typical numerical values are assumed from test results. First approximations are obtained simply and compared with second approximations and with more complete solutions. The effects of dihedral and of sweep back are shown in a series of graphical representations.

It is deduced from the assumptions made (1) that the angle of yaw under a disturbing force in the principal axis is a damped periodic oscillation; (2) that the angle of roll is essentially aperiodic so that oscillations can only occur at the beginning of the disturbed motion; (3) that the effect of the rudder on the rolling motion and on the line of flight can be increased in an extraordinary manner by the dihedral and sweep back effects.

Aircraft Design and Equipment

15 Metal Aircraft

Recent experiences in the construction and operation of metal aeroplanes. (C. Dornier, Berichte und Abhandlungen der W.G.L., Supplement to Z.F.M., No. 13, May, 1926.) (5.11/4952 Germany)

This is a general paper reviewing the development of metal aircraft. The principles underlying this method of construction are described in detail and particulars are given of the construction and performance of various all-metal aircraft.

Production of all-metal aeroplanes and seaplanes. (A. Rohrbach, J. Soc. Automotive Engineers, Vol. 20, No. 1, page 57, January, 1927.) (5.11/4948 Germany)

The article describes the technical principles underlying Dr. Rohrbach's organisation for the production of all-metal aircraft. Wing loading and power loading are discussed and the reasons for adhering to monoplane construction are explained. The advantages and disadvantages of side-by-side airscrews and of central tandem airscrews are stated, and wing construction is described, together with the design of flying boat hull. The time from design to completion for a new type of flying boat is given as sixteen months. The article is well illustrated.

16 Floats for Aircraft

(Paper read before the Soc. of Naval Arch. & Marine Engineers, November, 1926. Article in Engineering, December 3rd, 1926.) (5.34/4384 U.S.A.)

The article describes the progress of design of aircraft floats in America. Results are given of model basin tests of various single and twin floats and boats, and the limitations of such tests are discussed. The speed of the model is stated to be limited to fifteen knots.

17 Flotation Gear

(Army & Navy Register (U.S.A.), November 27th, 1926.) (5.342/4515 U.S.A.)

A test of flotation gear for carrier planes, recently conducted at the Washington Navy Yard, D.C., has proved to be very successful. A fuselage of a Boeing pursuit plane was loaded to 2,800 pounds with scrap iron. The flotation gear was installed on the turtleback of the fuselage and inflated with CO-2 before being lowered into the water. The test was conducted under the supervision of representatives from the Bureau of Aeronautics and was very satisfactory in that the fuselage floated with the tail well above the water.

18 Aircraft Carriers and Catapult Launching

Launching of the aeroplane carrier U.S.S. Lexington. (S. W. Wakeman, Engineering, December 10th and 17th, 1926.) (18.12/4957 U.S.A.)

This article gives the general dimensions of the carrier and the results of various tests made during the launching.

Catapults. (Aviation, Vol. 21, No. 26, December 27th, 1926.) (18.4/5001 U.S.A.)

Powder-propelled catapults have been perfected and are being installed on the battleships for launching observation and scouting planes. Also an amphibian type of airplane has been successfully launched from the catapults. These powder-propelled catapults operate successfully in the fleet and constitute a great improvement over the old type.

Launching amphibians by catapult. (American Press, Los Angelos.) (18.4/4381 U.S.A.)

A Loening amphibian has been launched from U.S.S. "West Virginia" by means of a "powder impulse catapult." Four battleships are already equipped with the new catapult which is said to be far more powerful than the compressed air type. The Loening amphibian weighs 5,100 lbs.

19 Photographic Equipment

Italian Photographic Equipment. (L'Aviazione, September 30th, 1926.) (14.21/4963 Italy)

Descriptions are given of :—

(*a*) An Auto Chronometer for automatically regulating the interval between the taking of air photographs.
(*b*) An automatic plate camera for tactical reconnaissance work. Type 1 for 60 plates, 18 cm. × 24 cm., and Type 2 has 60 plates, 13 cm. × 18 cm.
(*c*) An automatic film camera for strategic reconnaissance, taking 500 photographs 13 cm. × 18 cm.
(*d*) An automatic perspective air camera with interchangeable plate magazine for six plates 13 cm. × 18 cm., or for 80 films 13 cm. × 18 cm.
(*e*) An automatic camera for air survey with interchangeable plate magazine for 24 and 36 plates 13 cm. × 18 cm.
(*f*) A camera gun.

In each case, details are given of the size, weight and focal length of lens, etc.

The Gallas Air Camera. (Les Ailes, September 9th, 1926.) (14.21/4387 France)

This camera has been designed with the object of combining lightness with very simple manipulation. Its weight is 12 lbs. and the magazine carries 200 films (13 cm. × 18cm.) which can be exposed separately by the operator automatically. The movements necessary to operate the camera have been reduced to two.

Air Survey. (Annual Report of the Director of the Bureau of Standards, June 30th, 1926, page 7.) (14.1/4962 U.S.A.)

It is stated that the distortion which is introduced even with the best photographic lenses has been practically eliminated without introducing other harmful aberrations, by inserting at the proper place in the camera a plate glass of proper thickness. It is stated that this device reduces the flying time to about one-half that previously necessary.

20 Oxygen Apparatus

Oxygen Containers. An investigation of the effects of variations in the Radiation Factor on the Efficiency of Dewar Vessels. (B. Lambert and K. T. Hartley Proc. Roy. Soc., Series A, Vol. 112, No. A.760, p. 136.) (19.12/4632 England)

Results are given of experiments which include (*a*) a comparison of the efficiencies of three Dewar vessels of the same size, shape and material, one with the vacuum adjacent surface of the inner vessel only silvered, one with the vacuum

adjacent surface of the outer vessel only silvered, and one with both these surfaces silvered; and (*b*) a comparison of the efficiencies of Dewar vessels of polished vacuum adjacent surfaces of different metals. The surfaces chosen were polished silver, gold, platinum and copper.

Tests on Cylinders for Compressed Gases. (M. Ros, Schw. Bauz. 87, 269. Abstracted in Eng. Abstr., No. 29, October, 1926.) (19.12/5087 Germany)

The tests were carried out on pieces cut, both longitudinally and circumferentially, from cylinders some of which had burst in use, whilst some were still in use and others were new. They included tests for hardness, tensile strength, malleability and ductility, both on the cylinders as received and on annealed samples. Chemical analysis and micrographic examination were also employed. In many cases the cylinders were found to be insufficiently annealed, whilst some had also cracks in the metal. The author gives photomicrographs indicating the appearance of the annealed and unannealed samples, and a table of properties of the common commercial gases, with the corresponding size, thickness, strength, etc., of the cylinders required to hold them, according to the regulations issued in 1926. New cylinders are now tested by selecting and cutting up one or more of them for testing the metal. If the results are satisfactory, all the cylinders are stamped and admitted for sale. Every cylinder must also be tested by hydraulic pressure once every two or five years, according to the gas for which it is used.

21 Navigation Instruments

A New Compass. (L'Aero Sport, November 28th, 1926.) (6.344/4411 France)

A damped precession gyro pendulum in which the damping is due to the motion of a liquid contained in an annular vessel with the same axis of symmetry as the gyrostat is described. This vessel rotates slowly about this axis at a speed which is a function of the period of flow of the liquid in the vessel.

The disturbance of pendulums and gyroscopic apparatus through the accelerations expressed in aircraft. (Phys. Zs., 24, 344-350, 1923, Nr. 16, M. Schuler, abstracted in Physikalische Berichte, Vol. 24, p. 2038.) (6.32/5042 Germany)

Calculations are given showing that an oscillatory mechanical system with any imposed motion does not oscillate if its periodic time is the same as that of a pendulum having a length equal to the effective radius corresponding to the centrifugal force imposed on the system. Proof of this relation is given for some typical systems. The general proof is stated to involve difficulties.

Hirth's Patent for Map Holder for Aircraft. (German patent No. 428120/62c, 25. Zeitschrift fur Flugtechnik und Motorluftschiffahrt, August 14th, 1926.) (6.35/5114 Germany)

This map holder consists essentially of a rotating disc which is provided with a system for securing interchangeable map sheets and with a graduation in degrees, and is placed over a table on which the fore and aft line of the aircraft is shown. The invention is characterised further by the provision over the map of a disc made of glass or other transparent material bearing a system of lines parallel to the fore and aft line of the machine and also of a rule that can be moved over the map in a direction parallel to the fore and aft line of the machine. The direction of the most important air lines may be marked on the margins of the map sheet.

22 Engine Instruments

Report on Some Reflecting Flowmeters. (Archer, J. Sci. Instruments, 1926, 3,410.) (19.12/5034 England)

A short description is given of several types of jet-and-vane flowmeter developed for measuring small rates of gas flow in connection with an investiga-

tion of the evaporative losses of metal Dewar vessels. The following four instruments are described and figured:—(1) Pendulum type, with gravity control and electromagnetic damping; (2) horizontal beam type, with torsional control and fluid or electromagnetic damping; (3) voltmeter or ammeter types; (4) moving magnet type. The instruments are intended to be calibrated, but over the small angular working range used, the square root law is approximately true. Alternative systems of control and methods of damping are given.

Transmitting Thermometers, by L. Poincare. (L'Aeronautique No. 88, Vol. 8, September, 1926.) (6.45/5115 France)

This article is divided into four parts.

Part I. deals with the official specifications for transmitting thermometers. The chief difficulties are connected with obtaining the necessary accuracy of the readings between 25° and 140° ($\pm 1°$ is the accuracy required between 50° and 100°), also with the facts that the thermometer must be capable of withstanding temperatures of $-50°$ and be insensitive to variations of temperature in the transmitting tube and gauge; further, that the tube must be long (from 5 to 10 metres) and flexible.

In Part II. M. Poincare gives the theory of various thermometer systems. The ordinary thermometer acting by expansion and the gas thermometer being unsuitable owing to the length and deformability of the connecting tube, the vapour pressure system has to be adopted.

Part III. gives the principles governing construction. It is shown how to establish the ratio between the volume of the bulb and that of the connecting tube together with gauge. The advantages of the capillary system in the transmitting tube are mentioned and illustrated by short references to the "Area" and "Richard" thermometers. Further, the various factors entering into the selection of the transmitting fluid (usually ether, ethylchloride, methylchloride), the question of quantity and the difficulties connected with the fixing of the transmitting tube to the bulb are gone into.

Part IV. deals with the fitting of the thermometers, the best system being to introduce the bulb into a bend in the pipe between the engine and radiator. The fitting devised by "Le Thermometre Industriel," or L.T.I. Co., is specially mentioned and illustrated.

23 *Accidents, Cause and Prevention*

Fire Alarms on Aircraft. (Bulletin de la Navigation Aerienne, No. 77.) (16.12/4940 France)

The French have decided (Ministerial Decree No. 2782) that aircraft engines which are out of sight of the pilot and are not provided with automatic fire extinguishers must henceforward be provided with a fire alarm. Experience has shown that the effectiveness of fire extinguishers carried on aircraft depends essentially on the rapidity with which they are used, and it is therefore necessary that the pilot should be warned immediately fire breaks out. The use of a safety device, it is stated, will become obligatory on January 1st, 1927.

Parachutes—development and construction of the standard U.S.A. Army parachute. (J. Bonforte, Mechanical Engineering, Vol. 48, No. 11.A, p. 1234, November, 1926.) (16.11/4942 U.S.A.)

The article, which is well illustrated, gives the results of experimental tests made with this parachute and describes the trend of modern parachute development. As a result of the tests it was found that

(*a*) The variation of the porosity of the main sail apparently makes little difference in the time of opening.

(*b*) The weight attached to a parachute has little appreciable effect upon time of opening.

(*c*) The square of the rate of descent of two parachutes varies inversely as their porosities.

(*d*) That the square of the rate of descent of a parachute varies with the load.

Causes of accidents to French aircraft in 1926. (The Morning Post, January 28th, 1927.) (16.2/5050 France)

The following figures relating to accidents to French aircraft are stated to have been given by the Engineer-in-Chief of the French Aeronautical Inspection Dept.

During the year there were 1,261 accidents to military and 300 to commercial aeroplanes. Of the former, which were investigated by this official's department, 91 were of a serious nature, causing injuries to persons or proving fatal, and 1,170 of a less serious nature, *i.e.*, they merely interrupted the mission on which the aircraft was engaged.

Of the 1,170 less serious accidents, 1,012 were due to engine trouble, of which the following is an analysis: 258, including 65 cases of faulty carburation, were due to the feeding system of the engine, 174 to the ignition system, 164 to one or other of the moving parts of the motor, 140 to defects in the cooling system, 133 to the distribution system, 119 to the lubricating system, and there were 24 cases the causes of which could not be determined with certainty.

Of the 91 serious accidents, 32 were caused by engine trouble. Of these 32 cases, 23, including nine at the take-off, came from the feeding mechanism, two from the ignition system, two from the cooling system, and five from undetermined causes.

MATERIALS

24 *Elasticity*

Theory of Compression Tests. (Max Knein, Z.F.M., November 27th, 1926, p. 487.) (10.61/5116 Germany)

The author states the assumptions made:—

1. That the end plates applying pressure to the test piece are not deformed.
2. That the friction is sufficiently high to prevent the spread of the end area of the test piece.
3. The problem is rendered soluble with the use of the Airy stress function by restriction to two dimensions.

The edges are singular points in the solution and are determined by a stress function of suitable form.

The boundary conditions determine the arbitrary coefficients, and finally equating the determinant in the numerator to zero, Poisson's ratio m is determined as a function of n, from which it is found that $1.5<n<2$.

The stresses at the edges are of the order r^{n-2} and therefore become infinite.

Poisson's ratio.	Value of n.	Order of magnitude of edge stresses.
$m=2$	$n=1.58$	$r^{-0.42}$
4	1.75	$4^{-0.25}$

A discussion is given of the conditions for flow when the elastic limit is passed, the transition from elastic to plastic state offering great difficulties. A reference is made to Prandtl's solution for obtuse sections. Test experiments are not sufficiently analysable to offer a basis of comparison for agreement between experiment and calculation.

Rectangular plates supported along two parallel edges by yielding beams. (Emil Muller, Vienna, Z.f.M.u.M., October, 1926, pp. 355-366.) (10.61/5117 Austria)

The boundary conditions are found to be satisfied by developing the expression for the case of rigid supports in a Fourier Series and determining the coefficients to satisfy the more general problem.

A numerical example illustrates the methods.

Kinematics of three-dimensional frames. (Willy Prager, Darmstadt, Z.f.M.u.M., October, 1926, pp. 341-355.) (10.61/5118 Germany)

The author uses the methods of H. B. Mayer " Statique graphique des systemes de l'espace " introduced to German readers by v. Mises (Z. fur Math. u Phys., 1926).

Working out examples illustrate the methods.

25 *Research on Single Crystals*

Some further experiments on the behaviour of single crystals of aluminium under reversed torsional stresses. (H. J. Gough, S. J. Wright and D. Hanson, J. Inst. Metals, 1926. Advance copy abstracted in Chem. Abstr., Vol. 20, No. 21, p. 3418.) (10.64/5036 England)

The results of previous tests on single A1 crystals are reviewed. A polished cross-section of a single crystal bar that failed under alternating torsion showed two lines of " herring-bone " markings at right angles, representing differential hardening due to slip. A method of analysis of shear stresses is given, and the location of the markings is correlated with them. The hardness of the section varied with the intensity of the shear stress. Another specimen was tested in the same way, and its progressive hardening was traced in studying the method of fracture. The octahedral planes of the crystal were located by X-rays. Slip-bands corresponding to these planes were observed and photographed at various stages of the test. Slip was confined to the set of octahedral planes on which one of the resolved shear stresses was the greatest. In the stage of the test immediately preceding fracture slip did not occur, but fine cracks were propagated.

The interpretation of X-ray, single crystal, rotation photographs. (J. D. Bernal, Proc. Roy. Soc., Series A, Vol. 113, p. 117.) (10.64/5041 England)

The interpretation of single crystal rotation photographs divides itself into three parts. It is first shown by means of formulæ, tables and charts, how in the reciprocal lattice cylindrical co-ordinates can be found for each spot on the photographs. In the second part it is shown how to arrive at the dimensions of the true cell by means of the positions of the layer lines on the photographs. The third part consists in the attribution of the correct indices to the spots.

Several methods, of which the oscillation method is said to be by far the most valuable, are given for the separation of spots whose closeness leads to ambiguity in the ordinary rotational method.

26 *Light Alloys*

Light Alloy Technique. (Zeit. f. Metallkunde, January 19th, 1927.) (10.21/4939 Germany)

This journal contains a symposium relating to the development of the manufacture and use of aluminium and its alloys. Characteristic curves are given for Silumin, Skleron, Aeron, Lautal and Constructal. Other authors give an account of the practical application of these materials.

Properties of some sand-cast aluminium-magnesium silicide alloys. (S. Daniels, Ind. & Eng. Chem., Vol. 18, No. 12, December, 1926.) (10.21/5051 U.S.A.)

It is pointed out that magnesium silicide alloys do not possess valuable properties in the sand-cast condition, but when quenched and artificially aged, those quasi binary alloys which contain from about 1.25 per cent. to 1.75 per cent. of this compound develop an excellent combination of strength and ductility. The benefits to be derived from the heat treatment of alloys of this description are to be utilised rather in the wrought materials of which the proprietary 51.S alloy is an example. The metallography of the series is described and illustrated.

Strasser Alloys. (Der Motor Wagen, October 20th, 1926. Abstracted in Automotive Abstracts, p. 379, December 20th, 1926.) (10.21/4935 Germany)

Strasser alloys are sand-cast zinc-copper-aluminium alloys which possess remarkable aging properties. The alloy with 80 per cent. aluminium increases in tensile strength from about 17,000 to about 40,000 lbs. per sq. in. by twenty days' aging. Important improvements in Brinell hardness, bending strength, and notched bar impact strength are also secured. The aging sets in immediately on fast cooling after casting. The alloys seem stronger in the unfinished than in the finished state. It should be noted that a table seems to indicate the availability of certain American alloys which are about as strong as these German Strasser alloys. The new alloys are, however, said to be superior to silumin. Nevertheless, they seem as yet to be in an experimental stage.

Magnesium and its Alloys. (A paper by W. T. Cook and W. R. D. Jones read before the Institute of Metals at Liege and described in Engineering, December 10th, 1926.) (10.21/5127 England)

The paper gives a brief account of some preliminary experiments carried out with copper magnesium alloys. The results of tensile tests on chill cast material showed that the addition of small amounts of copper to magnesium was beneficial up to 2 or 3 per cent. For example, an alloy containing 1.88 per cent. copper gave an ultimate strength value of 9.7 tons per square inch, as compared with the 7.4 tons obtained from pure chill cast magnesium.

The production of aluminium and of magnesium in Italy. (Piero Ginori-Conti, Rass. min. met. chem. chim. 65, 30-3 (1926). Abstracted in Chemical Abstracts, Vol. 20, No. 21, p. 3416.) (10.21/5035 Italy)

A review of present developments.

The protection of duralumin from corrosion. (W. Nelson, Aviation, November 8th, 1926.) (10.27/4765 U.S.A.)

This article is a continuation of one commenced in the November 1st issue of this journal. The author deals at some length with the methods adopted for the protection of duralumin structures from the effects of corrosion. It is stated that corrosion may be retarded not only by such generally known methods as the use of paints and varnishes and the anodic treatment, but by polishing and buffing duralumin to a high degree.

The prevention of oxidisation in light metals used in aircraft construction. (L'Echo de Paris, November 17th, 1926.) (10.27/4967 France)

A memorandum was presented to the Academie des Sciences by MM. Jean Cournote and Jean Bary on the subject of the protection of light metals used in aircraft and more especially in seaplane construction.

The authors are stated to have succeeded in protecting aluminium and duralumin from oxidisation by covering these metals with a layer of copper, then with a layer of cobalt and chromium by the electrolytic process. Cadmium may be used instead of copper and covers aluminium very well.

Process for producing a protective coating of aluminium or aluminium alloy on metals liable to corrosion. (German Patent 426, 204, 48 b/9, 27.I.24/26 V.26. Held by G. A. Meker (Der Motorwagen, Vol. 29, No. 25, September 10th, 1926.) (10.27/4767 Germany)

The high temperatures required until now for depositing a film of aluminium of sufficient thickness on iron or steel have been an insurmountable obstacle to the application of such processes, the heat causing oxidation of both parts. In order to avoid oxidation, the process has often been carried out in a neutral atmosphere (*e.g.*, nitrogen). No films can be deposited below 500°C. For useful results higher temperatures are needed, and with the low melting-point of aluminium, the temperature range available is very small.

This difficulty is removed in the patent in question by the substitution of an Al-Fe alloy for pure aluminium.

This alloy, which has a melting-point considerably higher than that of pure Al, is laid over the specially prepared steel or iron surface in the form of powder and annealed in air. A two hours' anneal at 900°C. yields a film 0.2 to 0.3 mm. thick.

The influence of small amounts of various metals on the properties of aluminium. (By Takayasu Harada, Zeitschrift fur Metallkunde, Vol. 18, No. 2, February, 1926. Abstract, Memoirs of the College of Engineering, Kyoto Imp. Univ., Vol. III., No. 9. Paper in full.) (10.21/5119 Japan)

This paper deals with tests carried out by the author with a view to producing new alloys with improved properties for industrial purposes. The tests consisted in subjecting the alloys to the action of various acids, especially those contained in foodstuffs as the alloys were primarily intended for cooking utensils, in order to establish the effect of the various additions on the liability to corrosion. Having established that Cu, Ni, or Mn (unlike Zn) have a favourable influence, the author developed a new alloy "Halumin," the composition of which by analysis is as follows:—Cu, 1.48 per cent.; Ni, 2 per cent.; Mn, 2.3 per cent.; Fe, 0.47 per cent.; Si, 0.09 per cent.

Halumin has a sp. weight of 2.78, its resistance to corrosion is very high, and it can be welded much more easily than pure aluminium.

Influence of thermal and mechanical treatment on the resistance to corrosion of aluminium. (By W. Wiederholt, Der Motorwagen, Vol. 29, No. 25, September 10th, 1926. Abstract, Korrosions und Metallschutz, No. 2, 1926. Paper in full.) (10.27/4768 Germany)

The tests carried out by the author to investigate the effect of heat treatment on Al showed that 300°C. is the temperature at which the greatest amount of separated Si is found. As the temperature increases, increasing diffusion of Si in Al takes place, which means that the resistance to corrosion is improved since the presence of separated Si is detrimental from this point of view. As the mass involved in the diffusion increases with the duration of anneal, the resistance to corrosion tends towards the optimum value (as established for the given annealing temperature by the phase diagram) as the duration of anneal at temperatures over 300°C. increases. Once the optimum value has been reached, continued anneal has no further effect. If the test piece is slowly cooled, Si separates out. The concentration varies with the temperature according to the phase diagram, and at 300°C. the amount of separated Si reaches a maximum so that the resistance to corrosion reaches a minimum. Aluminium that had been annealed at 300°C. and cooled in air (this amounting to quenching in the case of aluminium owing to its high heat conductivity) gave minimum liability to corrosion as was anticipated.

As regards the influence of mechanical treatment, it was found that the resistance to corrosion decreases with the fineness of the grain. The fineness of the grain is decreased by re-crystallisation, in which the surface of the crystals (per unit of volume) decreases, this also decreasing the possibility of the formation locally of separate crystals of Al and Si.

Beryllium. (Engineer, November 26th, 1926.) (10.21/5038 England)

Some methods of production of beryllium are described. It is stated that nothing definite can yet be said regarding the general characteristics of beryllium alloys.

Beryllium. (Zeit. f. Metallkunde, Vol. 8, No. 9, September, 1926.) (10.21/4966 Germany)

Messrs. Siemens and Halske & Co. have taken over entirely the development of the production of beryllium, for which purpose a " Studiengesellschaft " (Research Co.) was founded in 1923 under the direction of Messrs. Siemens and Halske, the complicated laboratory process having now been developed sufficiently to enable production on a commercial basis to be undertaken. The extensive work commenced by the " Studiengesellschaft " will be continued by Messrs. Siemens and Halske, with a view to producing beryllium and beryllium alloys in commercial quantities and at economic prices.

27 *Heat Resisting Alloys*

Metals to resist corrosion or high temperatures. (H. J. French, Trans. Amer. Electrochem. Soc., 1926, 50, 47-81.) (10.17/4899 U.S.A.)

A résumé of the characteristics of metals and alloys used industrially to resist high temperatures or corrosion. The metals copper, aluminium, lead, tin, silver, nickel and iron, and their alloys, are considered. Tests on the steam erosion of metals made in Switzerland, in which a jet of steam was directed upon specimens of different metals at a stated velocity of 3,600 to 3,900 ft. per sec. for 70 hours showed that both low and medium carbon high-chromium steels, *e.g.*, stainless steel and iron, possessed favourable characteristics, but the best result was obtained with high carbon nickel steel which also contained appreciable proportions of chromium, silicon and manganese.

Heat Resisting Alloys. (Supplement to the Engineer, December 31st, 1926, p. 183.) (10.17/4950 England)

It is stated that a recent article by Dr. Fry (Kruppsche Monatshefte, October, 1926) indicates that German metallurgists have produced practical results in the development of alloys which remain practically unoxidised up to temperatures as high as 1300°C. Dr. Fry gives the results of his tests on a number of alloys, but does not state their compositions. Curves are given showing the resistance to oxidisation of various Krupp alloys from 900° to 1300°C.

Heat Resisting and Non-Corroding Steels. (An account of a paper read by Sir Robert Hadfield at the Minories. Engineering, January 14th, 1927.) (10.17/4938 England)

The article gives an account of Era heat resisting steel which has been developed with a view to preventing scaling and softening at high temperatures. At normal temperatures the maximum stress of Era heat resisting steel is 58.5 tons per sq. in., and at temperatures of 700°C., 800°C. and 900°C., maximum stress figures are given as 31, 24.6 and 19 tons per sq. in. A distinct type of Era steel, known as Era/A.T.V., is stated to be used for valves of high duty internal combustion engines.

Aero Engine Valve Steels. (Engineering, December 3rd, 1926.) (8.56/4388 England)

The article first refers to conclusions reached by Dr. Aitchison in 1919 (Engineering, Vol. 58, p. 799), who considered that a three per cent. nickel steel was suitable for all inlet valves and for exhaust valves working at a temperature not above 600°C. For exhaust valves subjected to temperatures of between 600°C. and 760°C. a high chromium steel was suggested, and for temperatures above 760°C. a tungsten steel was favoured. In a paper read before the Am. Soc. for Testing Materials (June, 1924) Johnson and Christiansen stated that the best results in their experiments were obtained with a steel containing from 11 per cent. to 13 per cent. chromium and 3 per cent. to 3.5 per cent. of cobalt together with a little molybdenum. This steel was recommended for ordinary operating conditions at high temperatures.

The article then describes Mr. Henshaw's paper read before the Royal Aeronautical Society (December 2nd, 1926). Experiments described by Mr. Henshaw included determinations of tensile strengths of materials at high temperatures, the Brinell numbers under various conditions, the tendency of each alloy to scale, the impact values at high temperatures and the coefficients of expansion. Tests were carried out over a temperature range of from 600°C. to 950°C. The high nickel chromium steels showed a smaller decline in tensile strength with increased temperature than the other materials. All materials, except nickel chrome steel, were found to have air-hardening properties. Mr. Henshaw considers that the introduction of high nickel chromium steel for the manufacture of heavy duty valves marks a step forward in this particular branch of metallurgy.

The choice of steel for the exhaust valves of aero engines. (Grard, Rev. Met. 23, 317-330. Abstracted in Eng. Abstr., No. 29, October, 1926.) (10.17/5086 France)

The author observes that the material of which aero engine valves are constructed must combine many qualities if the performance is to be satisfactory. He describes in detail the conditions under which such valves operate, and discusses the metallurgical aspect of the problem and the relative suitability of various alloys in regard to their properties, including (*a*) resistance to oxidisation; (*b*) temperature of the upper critical range; (*c*) hardness at high temperatures; and (*d*) high resistance to repeated impact when hot. As the result of experiments carried out at the Holtze steelworks on a range of chromium silicon steel, it appeared likely that three of these steels would prove satisfactory in service. The respective percentage compositions were :—

	Carbon.	Chromium.	Silicon.	Tungsten.	Molybdenum.
(1)	0.4	11	2.5-3	—	—
(2)	0.5	10	2.5	1.5	—
(3)	0.5	10	2.6	—	1.0

The author describes tests on engines fitted with valves corresponding with these analyses : (1) was a little soft and tended to seize in the guides; (2) and (3), which were rather harder owing to the small addition of a fourth element, were found to be particularly satisfactory.

28 Welding and Soldering

The fusion joining of metallic materials in aircraft construction. (S. Daniels, Mechanical Engineering, Vol. 48, No. 11.A, page 1240, November, 1926.) (10.11/4941 U.S.A.)

The author fully describes the technical methods of welding and points out that electric arc welding has not approached the degree of development attained by oxy-acetylene welding. Gas welding, particularly in fuselage construction,

has been applied not only to plain carbon tubing, but also to alloy steel tubing, particularly chrome-molybdenum. With plain carbon the strength of the joint is only 80 per cent. of that of the raw material, but the air-hardening properties of chrome molybdenum steel allows the full strength of the material to be developed. The use of brazing and soldering in aircraft is also discussed.

Test of Welded Seams by Rontgen Rays. (J. T. Norton, Iron Age, Vol. 118 (1926), page 409.) (11.26/5128 U.S.A.)

Seams effected either by autogenous or arc welding were examined in the laboratory by means of Rontgen rays. This method is too costly for use on a large scale, but is good for sample tests, as it reveals the defects and weaknesses due to the procedures employed in the various methods of welding and indicates the lines on which improvement must be sought. Norton used current of over 200,000 volts, but much lower voltages give equally good results for thin sheet, and the definition is better.

X-Ray Tests of Welds. (Power, 63, 800-803. Abstracted in Eng. Abstr., No. 29, October, 1926.) (11.26/5083 U.S.A.)

It has frequently been suggested that examination by X-rays should be of value in testing the soundness of autogenous welds, eliminating to a certain extent the usual tests, which involve destruction, or at least subjecting the weld to some stress. A 12in. weld specially made at the Union Carbide and Carbon laboratories was X-rayed at the Watertown arsenal, and was subsequently cut up for physical tests. Comparison of the X-ray indications with results of tensile tests and microscopic examination shows that the X-ray has a definite but limited value. Certain types of defect, particularly voids, are clearly shown. On the other hand, poor fusion at the junction of the weld and the base metal does not seem to register on the X-ray photographs. This would appear to indicate that at present it is unwise to conclude that if no defect appears on the plate the weld is necessarily sound. Further study is needed, not only to increase the effectiveness of the X-ray, but also to render the apparatus more suitable for shop use.

29 *Magnetic Properties of Permalloy*

(D. Pinnie, J. Roy. Tech. Coll., Glasgow (2), 1925, 5-7. Abstracted in Chem. Abstr., Vol. 20, No. 21, November 10th, 1926, p. 3426.) (10.16/4896 Scotland)

The initial permeability of annealed permalloy (78.5 per cent. Ni, 21.5 per cent. Fe) is thirty times that of the best soft Fe and a field as low as that of the earth will saturate the alloy to a magnetic intensity comparable with that of soft Fe. The magnetic properties are, however, very sensitive to strain, which causes a marked diminution of the susceptibility. Thus, a thin strip of permalloy after coiling and uncoiling exhibited magnetic properties similar to those of steel.

30 *Dopes and Varnishes*

Accelerated Weathering. (N. A. Nelson and F. C. Schmutz, J. Ind. and Eng. Chem., Vol. 18, No. 12, December, 1926.) (10.42/5079 U.S.A.)

The paper describes methods for accelerating the time required for testing paint, varnish and nitro-cellulose lacquer. The general principles underlying the formulation of a properly-balanced laboratory weathering cycle are discussed in this paper. The paper includes a consideration of the destructive influences of light, heat, humidity and temperature changes.

Cellulose Ester Dopes. (Der Motorwagen, Vol. 29, No. 25, September 10th, 1926, Abstract. Farbe und Lack 31.335, 1926, Paper in full.) (10.42/4774 Germany)

Celluose ester dopes are being used increasingly. They contain, in addition to an organic solvent, a basic substance such as nitro-cellulose, acetyl cellulose (and, of late, even formyl cellulose), and certain additions with a view to obtaining certain properties, for instance, softening substances (*e.g.*, castor oil) or hardening substances (such as resin and artificial resins). Pigments soluble in alcohol are used exclusively. Loading substances are only added occasionally in special cases. Nitro-cellulose dopes are inflammable, but acetyl cellulose dopes (the so-called cellon dopes) are a protection against fire. Nitro-cellulose is cheaper, more easily soluble and more durable than acetyl cellulose. The most important point in the preparation of such dopes is the correct selection of the solvents, as the dopes can only be made suitable for the various purposes for which they are intended by the correct combination of the different solvents. The physical properties being known, it is easy to establish the combination that will give the required kind of dope (quick drying, suitable for spraying, slow drying, suitable for spreading). The boiling points are only of subsidiary importance, the most important factor being the volatility of the solvent or of the mixture of solvents.

The manufacture of dope is comparatively simple if chemically well-defined esters are used, but it becomes difficult when, for reasons of economy, film and celluloid waste is also used since such waste invariably contains impurities and the quality is not invariable throughout.

Solvents for Nitro-Cellulose. (By Dr. F. Zimmer, Berlin-Tempelhof. Der Motorwagen, Vol. 29, No. 25, September 10th, 1926, Abstract. Farben Zeitung, 31-2350-1926, Paper in full.) (10.42/4770 Germany)

Solvents are an all-important question in the production of nitro-cellulose dopes.

Nitro-cellulose is a compound easily soluble in a number of organic solvents. Most of the solvents are unsuitable commercially owing to their prohibitive cost; others are useless owing to the fact that for many purposes solvents are required to be colourless, dehydrated, neutral and odourless, and also to have a certain degree of volatility and solubility and to stand mixing with other solvents. Of the remainder those that give definite qualities to the surface, such as durability and capacity for taking on good polish, are preferred.

The most suitable and useful solvents are acetic acid esters of alcohols with high boiling points and of hydrated phenols (*e.g.*, butyl acetate, amyl acetate, adrenol acetate, hexaline acetate). Methyl alcohol and spirit are added with a view to conferring given properties (elasticity, elongation, adhesiveness, weather resisting qualities, etc.).

Of late, phtalic acid esters with synthetic alcohols have been placed on the market.

31 Compositions

Novotext—a new material suitable for insulation and for construction of air-screws, etc. (Zeitschrift fur Flugtechnik und Motorluftschiffahrt, Vol 16, No. 7, April, 1925, Abstract. A.E.G. Mitteilungen, No. 2, February, 1925, Article in full.) (10.59/5120 Germany)

"Novotext" is a new material produced by the A.E.G. from textile fabrics laid in layers, impregnated with artificial resin and compressed when hot under high pressure to form sheets in size up to one metre square and up to 150 mm. thick; also tubes, bars and complicated sections. It is particularly tough and

strong, and in the manufactured conditions can be worked up with woodworking machines and tools.

Specific weight, 1.34.
Brinell hardness, roughly, 30.
Shock resistance in bending, up to 30 kg./cm.
Elongation, 0.0003.

These values vary according to the type of fabric (silk, cambric, linen, etc.). It is unaffected by hot oil up to 100°C., does not bend or warp, is not corroded by water, dilutes acids or alkalis, and is not soluble in alcohol, benzol, turpentine, etc.

Uses.—Novotext is suitable for airscrews, races for bearings of small gauge shafts, magneto contact breakers, linings for clutches and wheel brakes, and particularly suitable for camshaft and magneto driving gears, as, unlike bronze or steel gears, novotext gears show no signs of wear and run silently, even after long use.

Voltol—a new polymerised lubricating oil. (Nachrichten fur Luftfahrer, Vol. 7, No. 34, August 26th, 1926. Firm's data.) (8.41/5121 Germany)

Voltol is a lubricating oil subjected to a polymerisation treatment by incandescent discharges which has been evolved by the German firm Voltol Werke G.M.B.H. of Freital-Potschappel. Production is carried out in completely closed horizontal cylinders of a capacity of about 80 cubic metres. A number of electrodes over which the oil to be treated flows continuously are mounted on a rod fitted horizontally in the cylinder and in such a way as to be capable of rotation. A single-phase A.C. of 4300-4600 volts, 19-23 amps and a frequency of 500 is used for the production of the discharges which produce a polymerisation of the oil. The resulting increase in viscosity does not vary in direct ratio with the duration of treatment, but according to a quadratic law. With this process it is possible to produce oils with a viscosity at 100°C. up to 170 Engler degrees, that is, oils entirely satisfactory for all types of machine lubrication. The decrease in friction reaches 30 per cent.

According to tests carried out at the Charlottenburg Technical College, the increase per cent. in power obtained when using Voltol as a lubricant in a lathe instead of Russian machine oil was as follows:—

	at 46 r.p.m.	135 r.p.m.	220 r.p.m.
With lathe running light ...	24%	30%	30%
With lathe absorbing 1 k.w. ...	13%	13%	20%
With lathe absorbing 2 k.w. ...	6.5%	7.5%	10%

WIRELESS

32 *Wireless*

Ionisation of the Atmosphere and its influence on the refraction of short electromagnetic waves. (Hans Lassen, Z.f. Hochfrequenztechnik, p. 109, Vol. 28, No. 4, October, 1926.) (13.5/5122 Germany)

Part I.

The Austin formula for intensity of reception contains the factors $1/\lambda$ and $\exp(-Cr/\sqrt{\lambda})$, both of which diminish with λ. Practice has been developed accordingly, and for Nauen-Buenos Aires, waves of 18 km. are used. Waves of less than 100 m. are defined as short waves, and are the subject of the present paper.

Contrary to the conclusions drawn above, American amateurs found that short waves gave surprisingly good results with a fraction of the power. This effectiveness depends on the Heaviside layer of ionised gases, sharply defined at

its lower limit (about 100 km.). A discussion of the composition and ionisation of the atmosphere follows.

Part II. (November, 1925, page 139).

The author discusses further the Heaviside layer, its effective refractive index for different wave lengths, the plan of total reflection, and the resulting form of the path.

The refractive index diminishes with the wave length so that beyond a certain limit the wave will no longer return to the earth. This critical wave length appears to be slightly less than 15 m., and 14 m. may be taken as a limiting value on a day of strong ionisation of the length of waves which will return to the earth. The relative effect of free electrons on the refractive index is shown to be negligible compared with the effect of ionised hydrogen in the Heaviside layer.

Tables and curves are given of the refractive index for various heights and wave lengths. The paths of rays are also calculated and plotted, and the maximum range is estimated. The existence of dead zones and of the dependence of range, etc., on the time of day are discussed. Professor Forsterling, of Cologne, is thanked for initiating the work.

Polarisation of Radio Waves. (E. F. W. Alexanderson, Am. Inst. Elec. E., 45, 636-40. Abstracted in Eng. Abstr., No. 29, October, 1926.) (13.5 5085 U.S.A.)

The author discusses the phenomena which have been observed during short-wave transmissions with regard to apparent changes in direction, and shows that changes in the plane of polarisation would account for this and other similar irregularities in reception. Observations carried out in America on wave lengths of 50 m., transmitted from a directive antenna system, have indicated the possibility of horizontally polarising short waves, and that in most cases horizontal transmission and reception with short waves are superior to the old methods of vertical polarisation. The author describes a mechanical model for studying wave polarisation, which reproduces closely the effect of fading and illustrates the theory that fading is a phenomenon of wave interference. Experimental transmissions and measurements of a short wave radiated from a horizontal loop show that a continuously twisting plane of polarisation is produced with alternate points of plane and circular polarisation. The horizontal and vertical wave components have different velocities of polarisation, resulting in plane polarisation when in phase and circular polarisation when 90 degrees out of phase. From these observations the author concludes that horizontal polarisation is not confined to short waves only, although direct evidence can be obtained only at great heights.

Direction finding by Wireless. (J. H. Dellinger, Mech. Eng., Vol. 49, No. 1, page 29, January, 1927.) (13.4/4945 U.S.A.)

The chief interest of this article is the description and illustration of the double-beam directive beacon developed by the Bureau of Standards, U.S.A. A beacon of this type is in use at McCook Field.

ARMAMENT

33 Mechanism of Explosive Reactions

Photographic measurement of the rate of detonation of explosives. (J. Franklin Inst., p. 103, January, 1927.) (9.82/5047 U.S.A.)

The paper describes a photographic method of determining the rate of detonation and the results obtained by this method are compared with those

obtained by the well-known " Mettegang " Recorder. The experiments include detonation of columns containing explosives of different rates of detonation, and detonation simultaneously from both ends. It is concluded that photographic determinations of the rate of detonation of explosive are essentially the same in value as determinations made with the " Mettegang " Recorder. It is also concluded that some types of permissible explosives are flameless when detonated in the open.

Instruments for making Ballistic Determinations. Part II., Pressure Determinations. (Army Ordnance, United States, Vol. VII., No. 39.) (9.61/4740 U.S.A.)

The article describes the crusher gauge, a time pressure gauge and the Piezo electric pressure gauge. Crusher gauges are said to give an error of 15-20 per cent., and Piezo electric gauges are stated to be accurate to within .500 lb. per sq. in.; it is believed that this error will shortly be reduced to .100 lb. sq. in.

Properties of Initiating Explosives. (H. Kast, Z. ges. Schiess—u. Sprengstoffw., 1926, 21, 188-192. Abstracted in British Chem. Abstr. B., Vol. 46, No. 3.) (9.82/5000 Germany)

Increased power obtained by adding potassium chloride to mercury fulminate is not due to increased brisance, as the brisance of the mixture remains practically the same as that of the fulminate alone. The favourable effect must be attributed to an increase in the ease of ignition and quicker establishment of the detonation wave.

34 Bomb Fuse

U.S. Patent 1,596,224. (Army Ordnance, Vol. VII., No. 39, November-December, 1926.) (9.34/4630 U.S.A.)

The fuse covered by this patent is intended more especially for use with bombs. The object of the invention is to provide a fuse having an air propeller unscrew spindle carrying a spring-actuated firing pin with an improved form of locking means and release therefor.

AIRSHIPS

35 Airship Design

The Boerner Airship. (Scientific American, October, 1926.) (12.13/4390 Germany)

A design of airship, having certain unusual features, is described and is said to have been approved by competent German authorities.

The cross-section is roughly elliptical with a flat underside; although such a section increases the aerodynamic resistance, it is hoped that a larger dynamic lift will be obtained. The outer cover is double and contains a protecting mantle of nitrogen under pressure. The gasbags are subdivided, helium or hydrogen being contained in the upper part of each bag, coal gas in the middle compartments and air below.

Luftschiffbau Zeppelin's Patent for Envelopes of Rigid Airships. (German patent No. 431726/62a, 8.) (Zeitschrift fur Flugtechnik und Motorluftschiffahrt, September 28th, 1926.) (12.63/5123 Germany)

The fabric gores are made up of various materials in such a way that the actual light envelope fabric forms the largest middle or inner portion of each gore and is surrounded by a fabric of higher tensile strength. The corners or the points

to be first made fast to the longitudinal girders of the framework are provided with elastic reinforcement patches, the reinforcing fabric having a higher elongation than the cotton fabric used for the gores.

36 *Pochhammer's Patent for Airship Mast*

(German patent No. 432080/62a. 41.) Zeitschrift fur Flugtechnik und Motorluftschiffahrt, September 28th, 1926.) (12.41/5134 Germany)

In this patent the wind baffle cap at the top of the mast is replaced by a cone, open at both ends, which absorbs the energy necessary for the stabilisation of the airship from the wind. This cone, which may be either a single cone or made up of a number of cones arranged concentrically, being open at both ends, a powerful flow of air, accelerated by the diverging shape of the cone, is set up parallel to the longitudinal axis of the moored airship, this flow of air carrying with it sternwards the air surrounding the airship and thus protecting the latter from side gusts.

37 *Helium in Canada*

(J. C. McLennan, Nature, 117, 93, 1926, Nr. 2933.) (12.62/5039 Canada)

The richest gas was found in Ontario where the helium content was rather more than 0.8 per cent. The highest percentage of helium previously found is 0.34 per cent. The three wells referred to in the report produce 100,000 cubic feet of helium yearly.

MISCELLANEOUS

38 *Photo Electric Effect*

An Effect of Light on the Electron Emission from Hot Filaments. (W. H. Crew, Physical Review, December, 1926, Vol. 28, No. 6.) (6.79/4936 England)

Photo-electric currents from hot, oxide-coated platinum filaments.—The increase in the electron emission from hot, oxide-coated platinum filaments when illuminated by the full radiation from a water-cooled quartz mercury arc was measured, for different filament temperatures, as a function of potential between filament and anode. The photo-electron currents were large enough to be readily measurable with a galvanometer. Measurements on one filament showed the photo-electron current increasing with potential to a maximum at about 14 volts. For another filament, twice as thick, the maxima were between two and four volts. In the case of both filaments increasing the temperature shifted the maximum to lower values of potential. No photo-electric fatigue was observed. By the use of various absorbing screens and different sources of light it was found that the photo-currents are, for the most part, due to radiations of wave lengths shorter than λ 3000, but that the long wave length limit is somewhat above that value.

Photo-electron currents from other filaments.—In all, four types of filaments were tried: (*a*) oxide-coated platinum; (*b*) plain platinum; (*c*) oxide-coated tungsten; (*d*) plain tungsten. Of these, only the oxide-coated filaments gave an appreciable omission due to the light.

The possible source of the photo-electrons is discussed and calculations are made as regards their velocity distribution. Results suggest that the action of the light is to free electrons from a thin film of metal, of which the work-function varies with temperature of the filament.

39 *Altitude Chamber for Testing Instruments*

(Annual Report of the Director of the Bureau of Standards, June 30th, 1926, page 22.) (11.5/4951 U.S.A.)

Progress is stated to have been made on the fittings and equipment of a steel chamber which will be used to reproduce in the laboratory the low temperatures and pressures experienced in flight.

The chamber is designed to obtain low pressures corresponding to an altitude of 40,000ft. and temperatures down to −20°C.

40 *Temperature Inversion*

(Note in the Meteorological Magazine, Vol. 61, No. 732, page 291.) (6.23/5052 England)

A remarkable temperature inversion was observed by aeroplanes at Duxford on December 30th, 1926, the temperature readings being 34°F. at 890 mb. (3,700ft.), 51°F. at 850 mb. (4,900ft.), and 52°F. at 830 mb. (5,500ft.), giving a total rise of 18°F. The temperature at the upper level appears to be the highest yet recorded in the British Isles for the period December to April inclusive. The high readings were confirmed by another aeroplane ascent from Stag Lane Aerodrome, Hendon. Next day the inversion had vanished, the temperature having fallen 18°F. at 850 mb., and on the average 15°F. from 850 to 650 mb. (about 5,000 to 12,000ft.).

41 *Meteorological Conditions and Sound Transmission*

(E. S. Player, Quarterly Journal of the Royal Meteorological Society, October, 1926.) (15.13/4958 England)

The paper describes the results of flight tests carried out to determine the effect of various meteorological conditions on the range at which the aircraft can be heard on the ground. The effects of temperature, wind and humidity changes are discusssd. The records show that the range of audible transmission was good on every occasion that the general humidity of the atmosphere at all levels was high, and usually, but not always, poor when it was low. It is supposed that a high general humidity is associated with a homogeneous condition of the atmosphere, while low humidity is associated with heterogeneity.

42 *The Cup Anemometer*

(J. Patterson, Roy. Soc. Canada, Trans. 20, Sect. 3, pp. 1-53, January, 1926. Abstracted in Science Abstr. A, November 25th, 1926, No. 347.) (6.382/5037 Canada)

As no systematic attempt has been made since Robinson's time to find the most suitable type of cup anemometer, the author undertook a wind tunnel investigation and considered such factors as the length of the arm, size, number of the cups and constancy of the factor, and from the investigation he evaluated a general equation for all anemometers. The numerical results obtained are set out in a considerable number of tables. Among other results it is shown that the respective torques on the concave and convex sides of the cups are proportional respectively to $L(VR)$ 2.08 and $L(VR)$ 1.85. As there is this difference in the rate of variation of the torque on the two sides, it is not possible to get a cup anemometer with a constant factor. Neglecting the shielding of one cup on the other, and taking no account of the length of the arm or of friction, the following equation was obtained for the anemometer system:

$$\log f = 0.6334 - 0.12 \log V - 0.15 \log R.$$

The conclusions reached, in conjunction with S. R. Ferguson, for a Canadian and U.S.A. standard pattern are (1) three cups instead of four, (2) cups of 5in diameter, (3) arms 6.3in. long, and (4) a factor of 2.50.

43 Continuous Motion Produced by Vibration

(W. B. Morton and A. McKinstry, The Physical Review, Vol. 29, No. 1, January, 1927.) (6.72/5125 England)

A special case of motion of this kind was discussed recently by A. T. Jones. In the present note attention is called to a number of other cases in which the precise mechanism is obscure. A simple form of the phenomenon occurs when a mass is made to slip along a rough inclined plane, without loss of contact, by making the plane oscillate. This is examined mathematically. It is found that the motion may be either upwards or downwards, according to the relation between the direction of oscillation and the inclination of the plane. The results have been roughly verified by experiment.

AERO ENGINE FUELS OF TO-DAY AND TO-MORROW

[The following letter has been received by the Chairman in connection with his lecture on aero engine fuels. It raises several points of considerable interest in connection with the Diesel engine and fuels.—ED.]

General Motors Corporation,
224, West 57th Street,
New York,
January 17th, 1927.

DEAR COLONEL SEMPILL,

I was very glad to receive the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY containing your paper on aero engine fuels. A great deal of this paper could equally well be applied to motor car fuels, although the motor car fuel problem is somewhat different and very much more important because of the tremendous consumption.

I notice that in the discussion a good deal is claimed for the immediate probability of successful operation of aircraft engines operating on the Diesel, or some similar cycle. I certainly cannot agree with various of the statements made. It is undoubtedly true that petrol or gasoline is a more dangerous fuel than would be a heavy oil from a military point of view. On the other hand, in crashing, petrol is less apt to take fire on a hot exhaust pipe than is ordinary lubricating oil or Diesel engine oil. There are other possibilities in Diesel engines, such as the crankcase explosions and similar things, which I believe will go a long way to offset the increased safety in other directions.

The question of fuel cost, from a military point of view, can hardly be a controlling one. Commercially the cost of any fuel produced from petroleum is based partly on the heat content of the fuel in British thermal units and to a far larger extent on its availability value. In other words, on its general usefulness. Of course it is possible that in aviation a Diesel type fuel might be used, while the same fuel would not be sufficiently attractive for use in motor cars. In this case the low price of Diesel fuel might continue. At the present time the most commonly used aviation fuel is an unusually high grade motor gasoline and its price is therefore based on the cost of motor fuel.

Mr. Chorlton makes the statement that "any fuel that would burn could be used." This is certainly a most remarkable idea in view of the last fifteen years' experience in the operation of marine Diesel engines, where it has been found that the only safe oil to use is one having a considerable degree of refinement. Personally, I have seen no evidence whatever to indicate that the Diesel type engine is capable of supplying all the characteristics suggested by its proponents at one and the same time. If it is desired to obtain a high power output per lb. of weight from such an engine, it must be run at high speed and must use a very large proportion of all the oxygen available in each charge. When this is done I have never heard of a test to show fuel economies as low as can readily be obtained in the ordinary type of aviation engine. The reason is a perfectly simple one and is inherent in the difference between the two cycles.

The ordinary four-cycle engine begins to mix the air and fuel charged in the carburettor and the mixing continues accompanied by violent turbulence throughout the suction and compression strokes. The charge is then fired under maximum compression and with the maximum available expansion ratio possible with

the compression ratio used. In the Diesel cycle the injection of a charge begins only slightly before the period of maximum compression when turbulence in the cylinder is at a minimum and if the injection is continued over any considerable period of time, a good deal of the burning must be done at an expansion ratio even lower than is the case in the four-cycle engine.

It is true that some of the recent attempts at light engines with the Diesel cycle are really based on a modification of this cycle, in which the injection begins soon enough to raise the explosion pressure very considerably higher than the compression pressure. Such an engine is really a compromise between the Diesel cycle and the Otto cycle.

It is possible that this compromise cycle is the best one to work on in view of the necessity of building the ordinary Diesel engine heavy enough to take care of occasional misfiring. We know that explosion pressures in standard aviation engines regularly reach six hundred to seven hundred pounds a square inch and yet we see all Diesel engines built very much heavier in parts subject to the explosion pressure. The answer is obvious to me that it is necessary to build a Diesel cycle engine strong enough to stand an occasional attack of Otto cycle, with explosion pressures to correspond.

One of the important reasons for using high volatile fuel in aviation engines is the necessity of meeting a very wide range of temperature conditions with complete flexibility. I have never heard of any Diesel engine approaching the flexibility of the best Otto cycle engine. They can be designed or adjusted to run at various speeds, but to get one that is fairly efficient over a wide range of speed without continual hand adjustment by experts is an entirely new proposition.

It was a very great pleasure to see you in London and to meet the various gentlemen present at your extremely pleasant luncheon party. I still regret that our time was so short as to make it impossible to see many of the most interesting things available.

Sincerely yours,

(Signed) HENRY M. CRANE.

REVIEWS

"Fogs and Clouds"

By W. J. Humphreys. Baillière, Tindall and Cox, London. 18s.

Until a comparatively recent stage in civilisation clouds were regarded merely as a phenomenon of Nature beyond the ken of man. Their classification was "welcome" or "unwelcome," an alternative depending on the thirstiness of the soil and the present comfort of its inhabitants.

True, there have always been men with a natural bent for observation whose delight it was to follow the scenic changes of the sky and to chronicle them. In addition, poetic inspiration and artistic reproductions (frequently contradicting Nature herself) have provided data which was nebulous but not always in the required sense. But no definite system of cloud observation existed prior to the 19th century; and even in the 20th century it may be said that only a small minority understand the alphabet of this most open of Nature's books.

The progress of aviation has invested fogs and clouds with a new significance for the ordinary man, whose interest will assuredly be stimulated by Professor Humphreys' book. The main subject matter of this diverting publication was given as a lecture to the Franklin Institute in January, 1922. Since then the author has pursued his hobby of collecting cloud and fog photographs, and the present volume with nearly a hundred selected cloud reproductions may suitably be described as a picture dictionary of the heavens.

The original lecture has been amplified by historical sketches of John Aitken and Luke Howard, pioneers in this particular branch of meteorological knowledge. This human touch in a subject which the man in the street is led, through unfamiliarity, to regard as dry-boned, is characteristic of the author's presentation. Apt quotations from poets of the Nature school, the interpretation of quaint conceits such as "The Moon eats the Clouds," in which popular imagination has clothed the phenomena of the heavens and, of course, the fascinating and in many respects unique series of photographs, all combine to make a popular appeal.

The ordinary reader who has given no serious consideration previously to the meaning of fogs and clouds will find himself agreeably interested and enlightened, to the extent, it is hoped, of indulging in a little forecasting on his own account. The author's remarks on the behaviour and portent of cirrus cloud, pp. 40 and 41, are worthy of note in this connection.

To those with a direct interest in meteorology the book will be no less valuable, and the meteorologist or airman who may desire from time to time to refresh his mind on the meaning of fogs and clouds in relation to different weather types and to local geography, will find the brief and lucid explanations very helpful, especially as the remarks on cloud types have as their basis the most recent classification of the British Meteorological Office. Chapter II., on Fogs, admirably illustrated photographically, and Chapter IV.—a Cloud Miscellany—are eminently suitable for this type of reference.

The photographs were taken for the most part in America, but plates are included from Scotland (by Mr. G. A. Clarke, Aberdeen), Spain, Switzerland and South Africa. There are also pictures taken during the British Antarctic

Expedition. Professor Humphreys takes the view that observers should provide themselves with a comprehensive standard series of cloud photographs and, in viewing clouds, should match them with the appropriate pictorial representation, using a code which would enable named types in the international classification to be sub-divided. Except in the case of strato cumulus, which veils a multitude of skies, it is doubtful whether the matching tastes of different observers would agree sufficiently to make this complication worth while.

E.T.

Diesel Engines (Marine and Stationary)

By A. H. Goldingham. (Spon.)

In this book the author deals briefly with elementary thermodynamics, then with details of construction of compression ignition engines of the marine type, followed by some considerations of installation and operation. Considerably more space is devoted to descriptions of particular engines and the results of engine tests.

One very pleasing feature of the book is the very large number of general arrangement and detail drawings. These are well drawn, well printed and clear. The author is not critical but has confined himself to collecting data, so that the book is more useful for the draughtsman or for reference purposes than as a text book.

But the engines with which he deals are of the type which weigh 300 lbs. per b.h.p. Now in the near future the aeronautical engineer may have to consider seriously the adoption of the compression ignition engine using a heavy fuel oil as the power plant for aircraft. Those who are engaged in the production or development of aircraft engines may find it necessary to extend their knowledge of the compression ignition engine. The details of construction and performance of the compression ignition engine of to-day and its predecessors may be part of the knowledge which has to be acquired. For this purpose the book will be useful. But mainly, those who are looking ahead, will require a book which is critical and which sets forth the pros and cons of constructional methods and principles involved in an engine differing in many respects from those described by the author.

For aircraft, compression ignition engines will have to be of the high speed low weight per b.h.p. type. In the past the compression ignition engine has been the reverse in both respects.

The three main factors which influence the choice of an engine are reliability, low weight per b.h.p. and fuel consumption. Reliability is a matter of mechanical design and there should be no reason why the high speed compression ignition engine should be inferior in this respect to the petrol engine of to-day. Comparing the present day compression ignition engine with the petrol engine, the former gives a low fuel consumption for a high engine weight, whilst the latter has a higher fuel consumption for a lower engine weight. Which factor is the most important depends on the time of an individual flight. For the normal aeroplane flight, fuel consumption is of lesser importance. It may be necessary, therefore, to sacrifice to some extent the fundamental higher efficiency of the compression ignition engine in order to reduce its weight and so bring it more in line with the petrol engine. Such an engine will then differ from those of the past. Regarding the future compression ignition engine in this light, it follows that much of the present literature dealing with compression ignition engines will not apply to its successors for use in aircraft.

For this reason the book cannot be recommended to those of the aeronautical profession who have to be careful financially.

Air Facts and Problems

By Lord Thomson. Murray, 6/- net.

Lord Thomson has many claims to aeronautical distinction, not the least of which are that he was the first Socialist Secretary of State for Air and is Chairman of the Royal Aero Club. It is always dangerous for anyone holding a public position, and particularly for one who has or may hold a high political post, to write a book.

The Author has a command of language—he even speaks, or at any rate understands, American, judging by his constant references to the airplane—which makes his book very pleasant reading. It is quite amusing reading, too. He refers, for example, to Bishop Wilkins, who flourished in the seventeenth century, as "one of the founders and the first secretary of the Royal Society for Aeronautical Research." This comes well from one who has himself been described in the newspapers as Chairman of the Royal Aeronautical Club.

But apart from these light-hearted diversions, Lord Thomson's book is one which will cause many thoughtful men to ponder over the future of the air. He has the wisdom, too, which many of those high up in the councils of the air, both in this country and abroad have not, to realise the value of research.

"Perhaps the most far-reaching method of inculcating the air habit consists in enlisting the co-operation of the best brains of the country in aeronautical research. If they were certain of a career, however modest, many men of science, especially the younger ones, would devote their best efforts to the investigation of such questions as stability in flight, control, the use of metal in airplane (*sic*) construction and the improvement of engines. . . . Money expended on research is always a good investment."

The Socialist point of view has something to be said for it, if Lord Thomson expresses that point of view correctly. It comes well, too, from a man who says "the writer having neither technical knowledge nor experience in the art of navigation."

The book is illuminating in its chapters on the proposed rules of aerial warfare, co-operation between armies, navies and air forces and the British Empire and aviation. Of the proposed rules of aerial warfare, Lord Thomson says: "Unfortunately, experience shows that 'military necessity' tends increasingly to over-ride all laws. This is especially the case in air warfare, and it is foreseeable that, in practice, many articles of the new code, if and when it becomes international law, will be more honoured in their breach than in their observance."

The reviewer would like to remark that of all the silly things ever conceived by the mind of man, the laws of warfare are the silliest. Military necessity has broken down, in the long run, all such rules, and the observance or partial observance of the so-called laws of war by one combatant and not the other has led to disaster if not to actual defeat. If there had been no laws of war the Great War would have been over in far less time than it actually took. The framing of any rules of aerial warfare means exactly so much waste of time by those taking part in their preparation.

Lord Thomson very neatly sums up the situation. "When the dogs of modern war are unleashed, it is too late to muzzle them; if one pack starts muzzled, it will be eaten by others."